Arizona
Department of Transportation

WORKBOOK

for

MAJOR CONCRETE STRUCTURES INSPECTION (Course Number 204)

a training course developed
for the

ARIZONA DEPARTMENT OF TRANSPORTATION
Phoenix, Arizona

by

ROY JORGENSEN ASSOCIATES, INC.
Gaithersburg, Maryland

Revised by ADOT – October 20, 2006

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Directions To Workbook Users

Major Concrete Structures Inspection (Course Number 204) is one in a series of training courses on inspection and quality control for concrete construction. Other courses in the series include:

- Field Sampling and Testing for Concrete Construction (Course 201),
- Incidental Concrete Structures Inspection (Course 202), and
- Concrete Paving Inspection (Course 203).

This course is designed primarily for highway construction inspection personnel, but it also can be used in training other personnel.

This workbook is to be used in conjunction with a videotape presentation, discussion sessions with the trainee's instructor or supervisor, and other materials that make up the course. As sections of this workbook are assigned, each trainee should:

1. read and study the material to review previously presented information and gain additional details,
2. complete the exercises and quizzes as they are provided,
3. check his answers against those provided following the exercise or quiz,
4. review the material as needed to correct and clarify any incorrect answers, and
5. discuss any areas that are still not clearly understood with his instructor or supervisor.

Each trainee should be provided with his own copy of this workbook so that he can write in it and keep it for future reference and review.

This course is based primarily on the following sections in ADOT's *Standard Specifications for Road and Bridge Construction* and the corresponding sections in the *Construction Manual*:

- 203-5 – Structural Excavation and Structure Backfill
- 601 – Concrete Structures,
- 602 – Prestressing Concrete,
- 603 – Piling,
- 604 – Steel Structures,
- 605 – Steel Reinforcement,
- 609 – Drilled Shaft Foundations,
- 610 – Painting,
- 1003 – Reinforcement Steel,
- 1004 – Structural Metals,
- 1006 – Portland Cement Concrete,
- 1011 – Joint Materials, and
- 1013 – Bearing Pads.

Notes

First Discussion Period
(Introduction and Preparations)

Section One: Introduction And Preparations

Introduction to Bridges

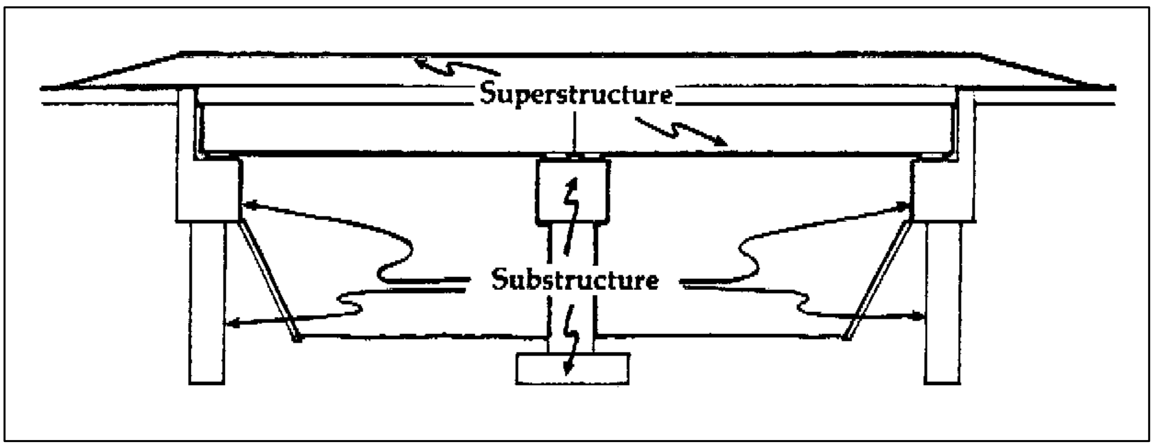
This introductory section reviews several basic areas of information on bridges, including:

- the primary parts of bridges,
- the commonly used types of bridges,
- variations in bridge design, and
- key aspects of bridges that distinguish them from other structures.

Bridge Parts and Terminology

Although bridges can vary widely by type and design, any bridge consists of two major portions, as illustrated below:

1. the **substructure** as the supporting portion below the bearing pads, and
2. the **superstructure** as the spanning portion from the bearing pads on up.



The major parts of the bridge substructures and superstructures are outlined below and illustrated on the next page.

Bridge **substructures** include:

- the bridge's **foundational elements** such as:
  - pilings,
  - spread footings, and
  - drilled shafts;

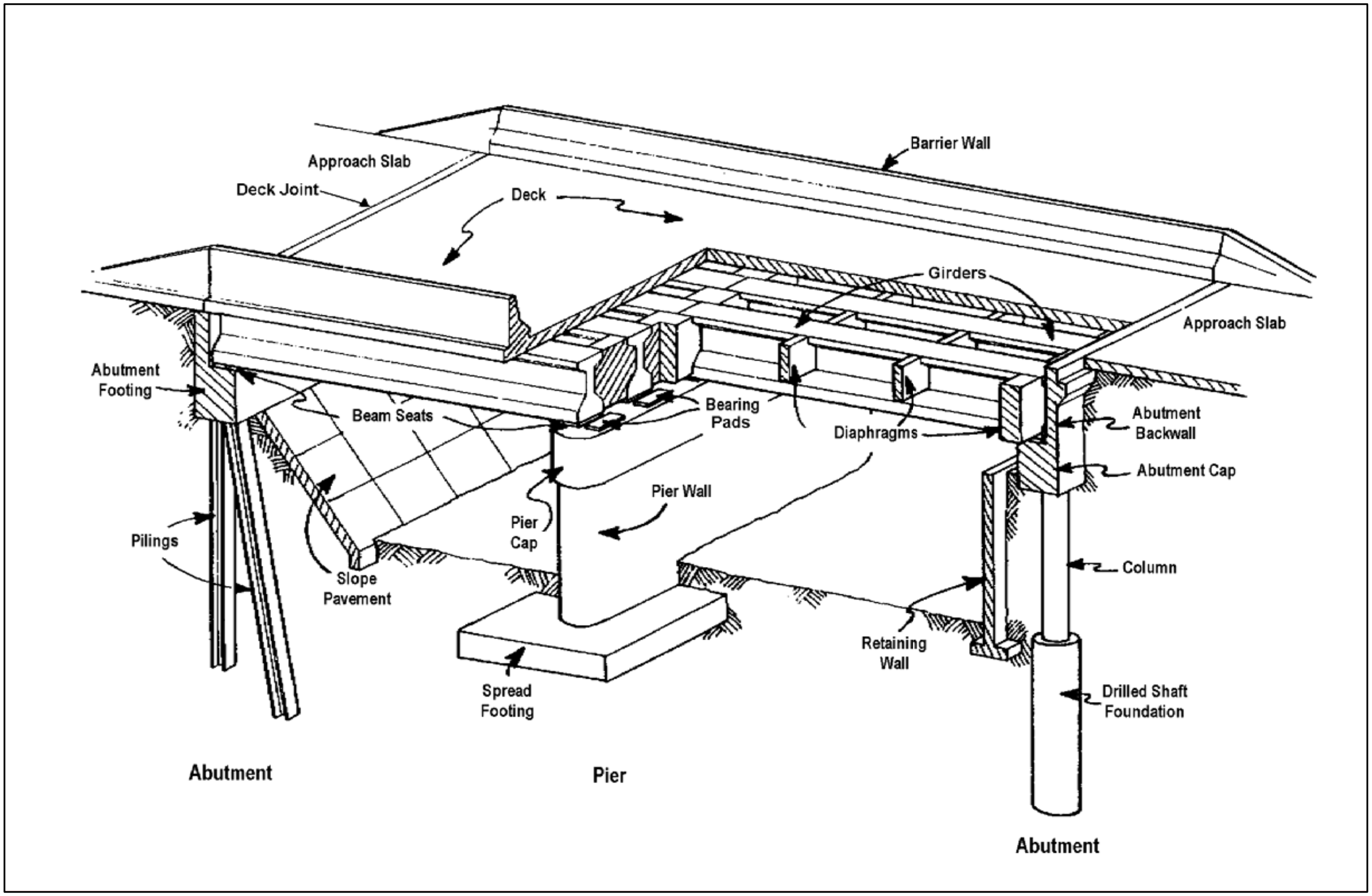
- two **abutments**, as the end supports, including:
  - their foundations,
  - a solid wall or series of columns,
  - the abutment cap and beam seats,
  - the abutment back wall,
  - wingwalls (not shown in illustration), and
  - erosion-prevention structures such as slope pavement and retaining walls; and
- one or more piers as intermediate supports for multi-span bridges, including:
  - its foundation,
  - a solid wall or series of columns, and
  - the pier cap and beam seats.

Bridge **superstructures** typically include:

- **bearing pads** on the beam seats;
- **beams and girders** to create the spans, including:
  - the main, longitudinal beams or girders, and
  - diaphragms at the piers, abutments, and intermediate locations;

- the **bridge deck** as the roadway pavement (or pavement base); and
- such **above-deck incidental** structures as barrier walls and curbs.

Bridge Parts and Terminology



Basic Types of Bridges

Bridges are generally categorized into types of beams or girders used in the superstructure. The more common types of bridges are summarized below and illustrated on the page 7:

- **steel girder** bridges, which include:
  - ➢ prefabricated steel girders that are erected into position, and
  - ➢ prefabricated steel diaphragms that are usually bolted to the girders;
- **Precast girder** bridges, which include:
  - ➢ precast (and usually prestressed) concrete beams that are erected,
  - ➢ cast-in-place concrete diaphragms, and
  - ➢ Precast girders; and
- **concrete box girder** bridges which:
  - ➢ are cast in place,
  - ➢ include a bottom slab, fascia and web walls, diaphragm walls, and a top slab as the deck, and
  - ➢ are usually post-tensioned.

Other less-common types of bridges include:

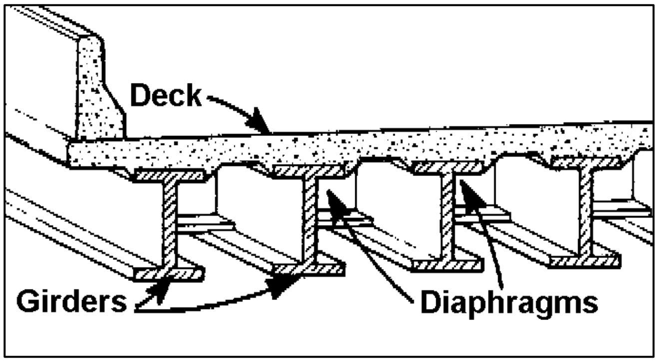
- **concrete box-beam** bridges, which are similar in cross-sectional appearance to box girders, but use precast box-beams that are erected into place; and
- **continuous concrete slab** bridges, which are cast in place without any beams or girders;
- **steel trussed** bridges; and
- **suspension** and **cable-stay** bridges.

Variations in Bridge Design

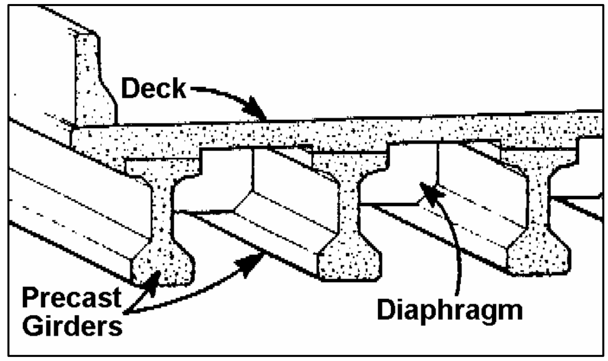
In addition to variations in types of beams or girders, bridges differ from each other in such key areas as:

- types of foundations (spread footings, pilings, or drilled shafts);
- pier and abutment design (cylindrical columns, flared columns, solid walls, etc.);
- erosion-protection treatments around abutments (slope pavement, retaining walls, wing walls, etc.); and
- types of above-deck incidentals (barrier walls, curbs, sidewalks, pedestrian fencing, etc.).

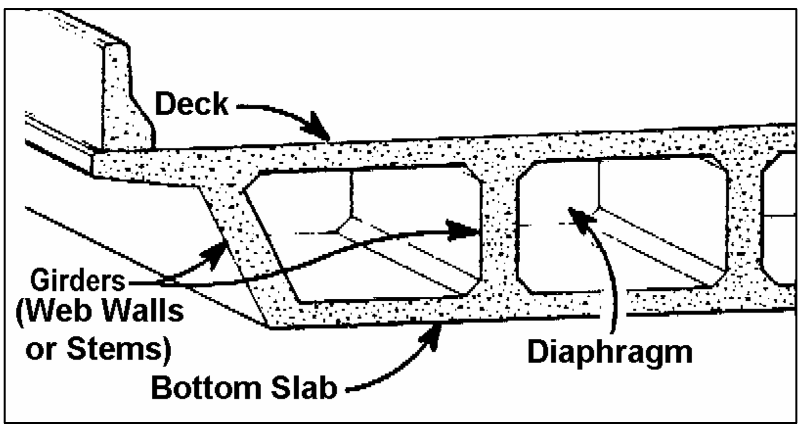
Basic Types of Bridges



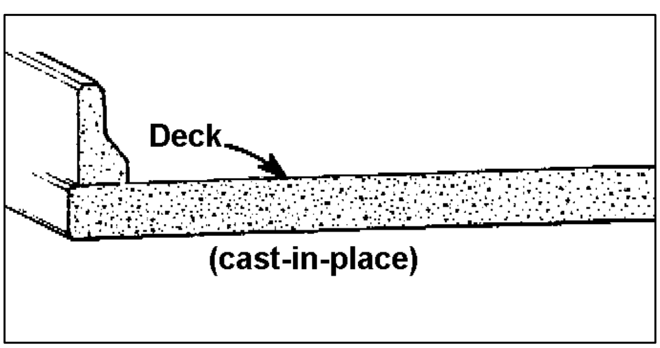
Steel Girders



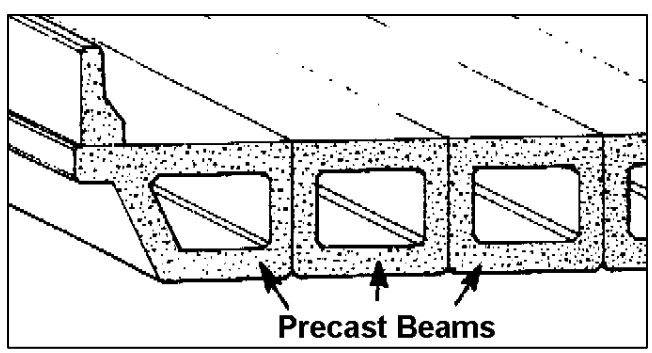
Precast Girders
(AASHTO)



Cast-in-Place Concrete Box Girders



Continuous Slab



Concrete Box Beams

Bridge designs vary widely because each bridge is designed to meet the specific needs of its location. Differences among bridges are usually attributable to such variables as:

- subsurface soil/rock conditions,
- the type and size of roadway or drainage channel to be spanned,
- the traffic volumes and loads to be carried on the bridge,
- aesthetic considerations,
- individual preferences of different designers, and
- type of terrain.

This course cannot cover all possible variations in bridge design – nor every acceptable method or technique that a contractor might use in bridge construction. It does, however, concentrate on those bridge designs and construction methods that are generally more typical or representative of all bridges.

Key Aspects of Bridges

Although a variety of materials can be involved in bridge construction, the primary material in most bridges is concrete. So many of the construction methods – and inspection points – in bridge construction are the same as for other concrete structures, including:

- such preparatory work as:
  - establishing alignment and grade controls,
  - structural excavation and/or soffit fill,
  - setting forms and falsework, and
  - placing reinforcing steel and/or post-tensioning ducts;
- the concrete placement operations of:
  - delivery and discharging the concrete,
  - consolidating the concrete,
  - finishing unformed surfaces,
  - constructing joints, and
  - minimum placement rte of 35 CY/h (see 601-303(A)); and
- completing the structure by:
  - curing the concrete,
  - removing forms and falsework,
  - finishing formed surfaces, and
  - backfilling around the structure.

From this standpoint, the primary differences between bridges and other structures are the larger quantities of materials and the more numerous repetitions of the basic concrete construction operations.

However, certain parts of bridges involve special requirements or construction methods that are relatively unique to bridges and distinguish them from other, smaller concrete structures. These include:

- special types of foundations, such as pilings and drilled shafts;
- key considerations for piers and abutments;
- various methods for different types of beams and girders; and
- specific requirements for bridge deck construction.

The bulk of this course concentrates on the key aspects of bridge construction in these primary areas.

Preparations for Bridge Construction

Due to the relative size and complexity of most bridges, preconstruction preparations are particularly important – both in the office and in the field.

Preparations in the Office

An inspector's preconstruction preparations for a bridge project can begin in the office. As soon as possible before the construction begins, you should:

- thoroughly review all contract documents, including;
  - the plans and special provisions for the project,
  - the appropriate standard specifications, supplemental specifications, and standard drawings that will apply, and
  - any contract-provided documents such as traffic control plans, necessary Drilling Documentation and Safety Plan, falsework and forms designs, and shop drawings for prefabricated items;
- check and verify all (time permitting):
  - plan dimensions,
  - elevations, and
  - materials quantities;
- list any discrepancies that are discovered and report them to your supervisor (along with any items that may require clarification); and
- set up part of your inspection documentation records in advance so that the actual dates, dimensions, quantities and other values can be more easily filled in as the work progresses.

Although inspectors rarely participate directly in the preconstruction conference, you should check with the Resident Engineer after the conference to identify any areas of special concern.

Preparations in the Field

Once you have started familiarizing yourself with the plans and other contract documents, you should visit the project site to continue your preparations. In the field, you should compare the site with the plans in terms of:

- the locations of existing utilities, both underground and overhead;
- the layout and elevations of the existing ground and any existing structures, vegetation, or other features that may be affected by the construction;
- any water or drainage conditions that may require special attention;
- the proper locations, clear identification, and adequate information of the initial alignment and grade contract stakes; and
- proper implementation of the approved traffic control plan. If any discrepancies are discovered in the field, report them to your supervisor.

Section One Quiz

1. Which of the following are parts of a bridge's <u>super</u>structure? (Circle one or more)
   a. pier columns
   b. steel girders
   c. abutment caps
   d. beam seats
   e. bearing devices
   f. diaphragms

2. Which of the following are parts of a bridge's <u>sub</u>structure? (Circle one or more)
   a. the bridge deck
   b. pier caps
   c. retaining walls
   d. precast concrete I-beams
   e. barrier walls
   f. pilings

3. Bridges are generally categorized into types by variations in which of the following parts? (Circle one)
   a. bridge foundations
   b. piers and abutments
   c. beams and girders
   d. the bridge deck

4. As part of your preconstruction preparations in the office, which of the following should be checked in detail to verify their accuracy? (Circle one or more)
   a. planned quantities of reinforcing steel
   b. the dimensions of each part of the bridge
   c. all elevations shown in the plans
   d. all of the above

5. If you discover a discrepancy between the plans and the actual site during your preconstruction preparations in the field, you should ... (Circle one or more)
   a. change the plans to fit the actual site.
   b. report the discrepancy to your supervisor.
   c. discuss the discrepancy at the preconstruction conference.

Section One Quiz Answers

1.	b.	steel girders
	e.	bearing devices
	f.	diaphragms
2.	b.	pier caps
	c.	retaining walls
	f.	pilings
3.	c.	beams and girders
4.	d.	all of the above
5.	b.	report the discrepancy to your supervisor.

Notes

Second Discussion Period
(Bridge Foundations)

Section Two: Bridge Foundations

The foundations of a bridge are particularly critical because the bridge must support both its own weight and the traffic loads that it will carry (dead load/live load).

For many smaller concrete structures that do not directly support traffic, a firm soil foundation is usually adequate. Other incidental structures use footings as part of the structure for additional support. However, the size and traffic-bearing function of a bridge demand special attention to its foundations. At the very least, spread footings are needed to provide foundational support for bridge piers and abutments. Sometimes special types of foundations – such as driven pilings or drilled shafts – are needed to firmly anchor the bridge into the ground and provide adequate support.

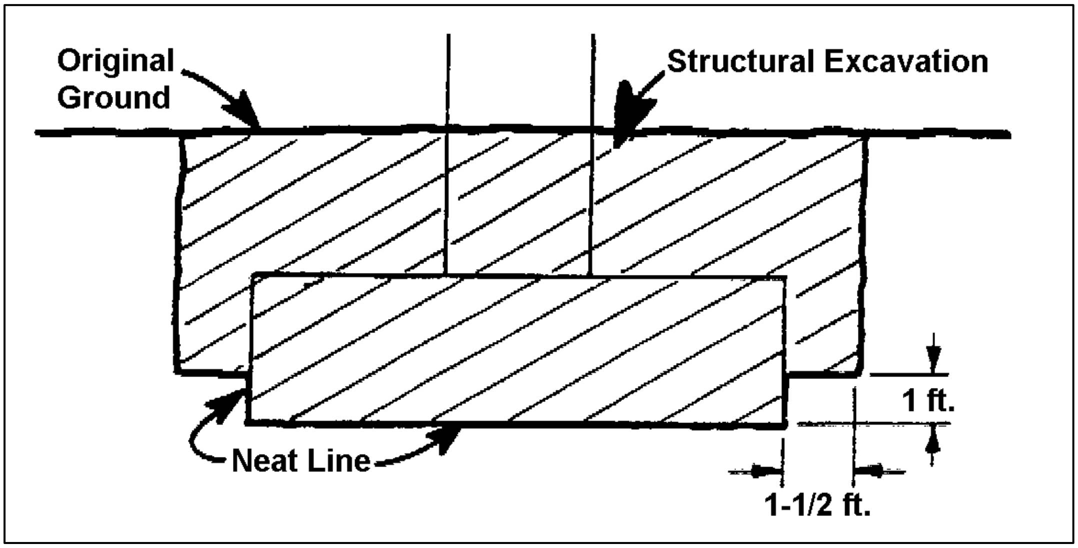
This section summarizes some key aspects of structural excavation and concrete footings for bridge foundations, but it concentrates in more detail on such special bridge foundations as pilings and drilled shafts.

Structural Excavations and Embankment

Because the planned elevations for the bottom portions of bridge substructures rarely match the elevation of the existing ground, it is usually necessary to excavate down to the planned structural elevation or build up an embankment to the specified level.

Structural excavation for bridges must meet the same standard requirements as for other concrete structures. When structural excavation is needed, see that:

- the original ground is cross-sectioned before the excavation begins;
- the sides of the excavation are adequately sloped or braced as needed for safety;
- the excavation is completed to at least the structural excavation limits as specified in the plans (as shown in the example on page 15) and including:
    - the correct elevation for the bottom of the structure along the “neat line” at the bottom of the excavation, and
    - adequate space for forms and workers outside the sides of the structure (usually about 1-½ feet outside and 1 foot above the bottom edge of the structure);
- the foundation for the structure at neat line is firm, uniform, and level with either:
    - undisturbed original earth, or
    - solid rock (with any seams grouted);
- any unstable material is removed and replaced with suitable structural backfill material that is placed in layers of 8 inches or less and compacted to at least 95 percent of its maximum density;
- the contractor removes any water from the excavation and keeps the foundation dry until after the concrete is placed and set;
- the boring logs are located and compared with field conditions; and



- any over-excavation is backfilled only with structure backfill (see 203-5.03(A)).

When embankments must be built-up as part of a bridge's foundation, see that:

- all clearing and grubbing is completed before embankment construction begins;
- the embankment material is properly placed:
  - in horizontal layers of 8" or less,
  - with adequate moisture for effective compaction, and
  - with each layer compacted to at least 95 percent of the maximum density;
- any rocks or broken concrete larger that 3 inches in size within the embankment are at least:
  - 2 feet below the surface, and
  - 3 feet horizontally from the plan location for any piling, drilled shaft or other structure;
- the top of the embankment is completed to the corrected elevation as specified in the plans; and
- no large rocks, broken concrete, or debris is placed at the planned locations for drilled shafts and driven piles.

Bridge Footings

Concrete footings often are used as the foundational elements for bridge piers and abutments. They provide foundational support by spreading structural loads over a larger area so that such vertical elements such as walls or columns cannot be displaced or settle into the ground.

The construction procedures and inspection requirements for concrete footings are basically the same as for other cast-in-place concrete structures. These will be discussed further in conjunction with other concrete elements of the substructure in Section Three of this course.

Pilings

(Optional Reading)

Pilings provide foundational support by serving as anchors that extend into the ground beneath the structure. They are typically used in locations where soil conditions near the bottom of the structure would not provide adequate bearing for a concrete footing by itself.

Types of Piles

The type of piles to be used will be specified in the plans. They may be:

- steel H-piles – forged steel beams with an H-shaped cross-section;
- cast-in-place concrete piles – consisting of cylindrical steel shells that are driven into the ground and then filled with concrete; or
- other, less commonly used types such as:
  - precast concrete piles (which may be either conventionally reinforced or prestressed), and
  - timber piles.

Although many of the requirements for pile driving apply to all types of piles, there are some special methods and requirements for different types. This section will concentrate on steel H-piles and shells for cast-in-place concrete piles as the most common and representative types.

Pile-Driving Equipment

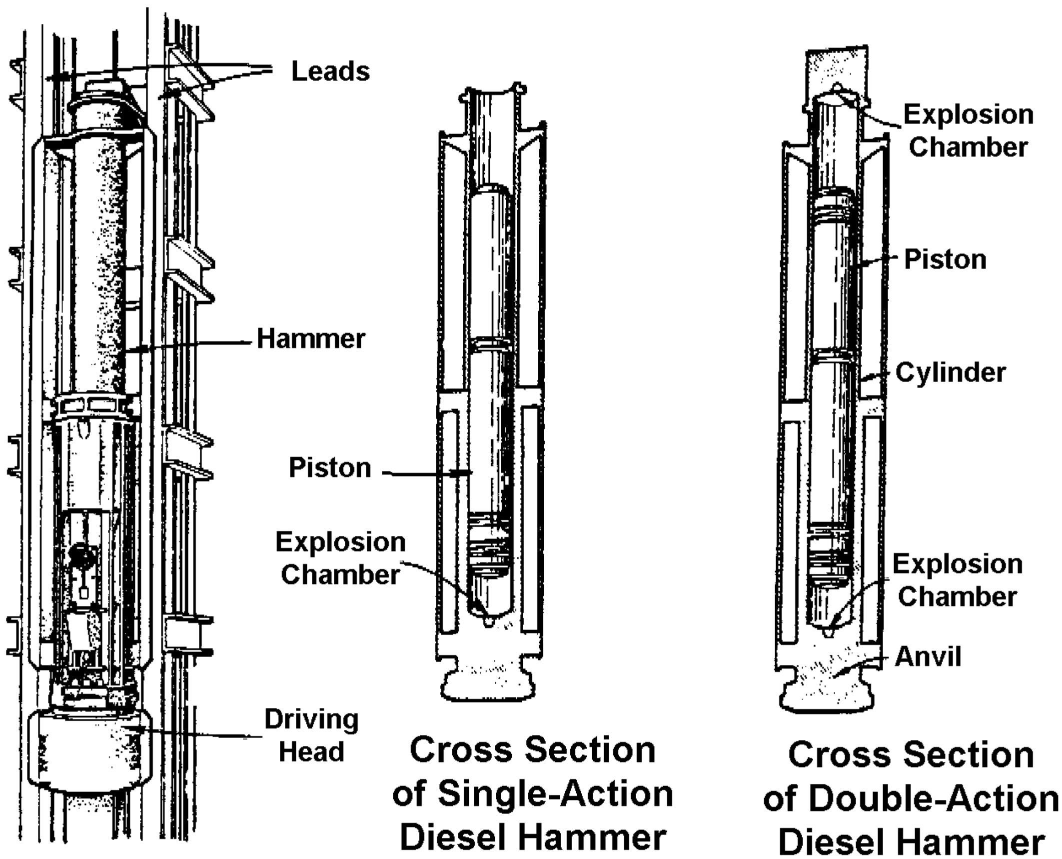
As shown on the next page, the equipment used in driving piles consists of three basic parts:

1. a hammer to provide the driving force,
2. a driving head to transfer the impact to the pile and protect it from damage, and
3. a set of rigidly supported leads to guide the hammer and driving head.

There are also several different basic types of pile-driving hammers, including:

- gravity or drop hammers, which are allowed only for timber piles and are rarely used;
- powered hammers, which may be:
  - driven by diesel (most common), steam, or compressed air, and
  - single-action (more common) or double-action, as illustrated on the next page; and
- hydraulically driven hammer.

Pile-Driving Equipment



The equipment must meet certain minimum requirements, including:

- an appropriate type of hammer must be used for the type of pile being driven as follows:
  - ➢ a powered hammer with a capacity of at least 15,000 foot-pounds per blow, for steel H-piles and steel shells without a mandrel,
  - ➢ a powered hammer with a capacity of at least 10,000 foot-pounds per blow, for steel shells if a mandrel is used, or
  - ➢ a drop or gravity hammer for timber piles;
- the driving head must be the proper type and size for the type of pile being driven (including a cushioned driving head for precast concrete piles); and

- the leads must:
  - be straight, rigid, and well supported, and
  - allow free movement of the hammer and driving head.

Preparations for Pile Driving

In preparing for pile-driving operations, you must first see that the site is ready, including:

- completion of any excavation or embankment work so that the site is at the correct elevation for pile entry as specified in the plans; and
- accurate layout and staking of the entry points for the pilings.

As piles are delivered to the project site, you must inspect them for acceptance as follows:

- check to see that they are the type and size as specified in the plans;
- for steel piles and shells:
  - check and document the heat numbers on the piles or shells, and
  - see that a Certificate of Analysis has been submitted covering the heat numbers;
- see that all piles are straight and rigid without any bends, twists, or cracks;
- see that they are properly stored and handled such that:
  - steel piles or shells are stored off the ground and out of mud or water to avoid excessive rusting, and
  - precast concrete piles are handled only at the designated lifting points: and
- see that they are properly fitted with driving tips, including:
  - cast steel points for steel H-piles (if so specified in the plans), and
  - closed driving tips that are no more than ½-inch larger than the diameter of the shell at the tip for steel shells.

You must also prepare for pile-driving operations by:

- marking each pile for monitoring penetration, including:
  - the first 10 feet, and
  - each 1-foot thereafter to the top of the pile;
- referring to the plans to determine the basic criteria for in-place acceptance, in terms of:
  - the required tip elevation or penetration,
  - the minimum bearing value, <u>or</u>
  - the specified combination of tip elevation and bearing value; and

- obtaining and documenting the necessary specifications for the make and model of equipment being used, including:
  - the weight of the hammer,
  - the interior fall distance[1] of the hammer, and
  - for double-action hammers, either the manufacturer's energy rating or the effective piston area and the mean pressure.

Pile-Driving Operations

As pile-driving begins for each pile:

- see that it is accurately positioned for entry at the correct location;
- see that it is properly aligned in accordance with the plans so that it is either:
  - plumb, or
  - at the specified batter;
- watch for any shifts in position or alignment during the initial driving and recheck the plumb or batter as needed; and
- check noise levels in urban areas.

Although the criteria for in-place acceptance of piling may be <u>either</u> a required elevation <u>or</u> a minimum bearing value, you must determine <u>both</u> the penetration and the final bearing value for each pile, for as-built documentation purposes.

To monitor and document the penetration of each pile as it is driven:

1. count and record the number of hammer blows used to drive the pile to the 1-foot mark; and
2. continue counting and recording the number of blows to each 1-foot mark thereafter, until the required penetration and/or bearing value is achieved.

To determine the bearing value to each pile as it is driven:

1. Select the appropriate formula to be used from those shown on the next page;
2. Determine the average penetration(s) by
   a. marking a reference point on the pile and leads,
   b. counting ten consecutive blows,
   c. marking and measuring the penetration after the ten blows, and
   d. calculating the average penetration per blow;

[1] For single-action power hammers, the total fall distance is variable depending on the resistance to each blow. You can see the top of the hammer's piston as it rebounds above the top of the cylinder, but you must know the interior distance to determine the total fall of the hammer.

3. Determine the fall distance (H) of the hammer by, either:
   a. observing the fall for gravity hammers,
   b. observing the rebound above the cylinder and adding this distance to the internal fall distance for single-action power hammers, or
   c. using the manufacturer's data for double-action power hammers;
4. Calculate the bearing value using the appropriate formula from those shown below;
5. Repeat the bearing value determination as needed until the required penetration and/or bearing value is achieved;
6. Record the final bearing value; and
7. Record the total length of each driven pile.

<u>Pile Bearing Value Formulas</u>

For drop hammers: $P = \dfrac{2WH}{S+1.0}$

For single-action power hammers: $P = \dfrac{2WH}{S+0.1}$

For double-action power hammers: $P = \dfrac{2H(W+Ap)}{S+0.1}$

OR

$P = \dfrac{2E}{S+0.1}$

With:

P	=	Bearing value
W	=	Weight of hammer, in pounds
H	=	Fall of hammer, in feet
S	=	Average penetration, in inches per blow
A	=	Effective area of piston, in square inches
p	=	Mean effective steam or air pressure, in pounds
E	=	Manufacturer's energy rating, in foot-pounds per blow (approved by the Project Engineer)

Pile Splices

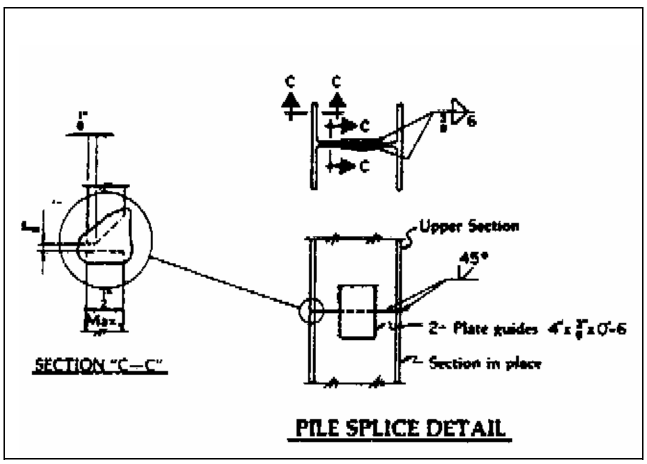
Pilings are usually provided in sufficient lengths (usually 40 feet) to reach the depths indicated in the plans.
However, splicing is sometimes needed in such situations as when the required bearing value cannot be achieved at the planned depth.

In terms of different types of piles:

- steel H-piles and shells are commonly spliced;
- timber piles may not be spliced, except with the Engineer's approval; and
- precast concrete piles may not be spliced but may be extended with cast-in place concrete when authorized by the plans or the Engineer.

When steel H-piles or shells are spliced:

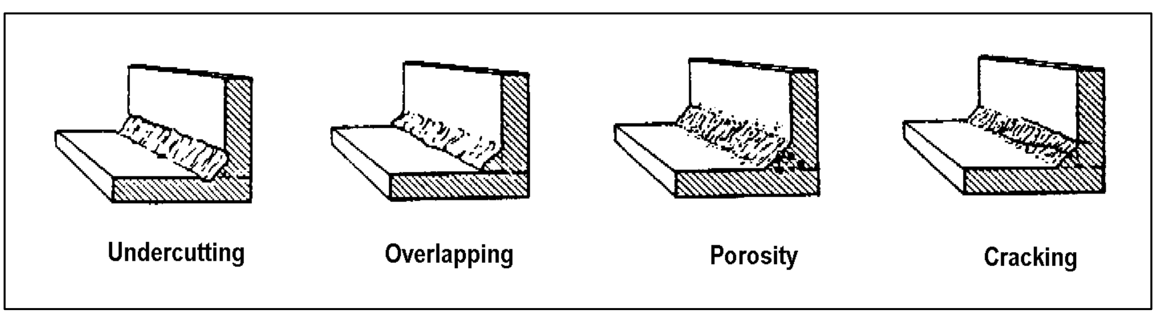
- see that a full-weld splice is made in accordance with the plans or standard drawings (as shown below, from Standard BM-1);



<u>Pile Splice Note</u>:

When piling is to be spliced for further driving, upper section shall be lowered on section in place and tapped lightly with hammer to full bearing before butt welds are made. When piling is to be extended without further driving, omit guide plates and make butt welds continuous across web.

- make sure that all welding is done by a certified welder;
- check the welding for such defects as undercuts, overlaps, porosity or cracking (as illustrated below);



- measure and record the length of the spliced portion;
- record the source of the spliced portion as “stock” or by the pile number from which it was cut off; and
- continue the 1-foot markings on the spliced pile for monitoring penetration.

Pile Cut-Off

After pile driving is completed, all piles must be cut off at the elevation specified by the plans. During pile cut-off operations, see that:

- all cut-offs are perpendicular to the axis of the pile;
- each cut-off pile provides the proper depth of embedment and type of anchorage as shown in the plans;
- each cut-off portion is:
  - marked with the pile number from which it was cut,
  - measured for its length, and
  - accounted for as “on hand,” “contractor use”, or “in-place” (by the pile number to which it is spliced). Payment stops at the cut-off point
- less than 5 feet of cut-off goes to the contractor.

Special Considerations

There are several special considerations that must be given for pre-drilled holes and completing cast-in-place concrete piles.

Holes are pre-drilled for piles only when specified by the plans or ordered by the Engineer. See that any pre-drilled holes:

- have a diameter of at least 6 inches greater than the widest cross-sectional dimension of the pile;
- are drilled to the correct vertical or battered alignment;
- are drilled only to the depth specified in the plans; and
- are backfilled with dry sand, pea gravel or other material around the pile as specified in the plans after pile driving is completed.

For cast-in-place concrete piles, the driving of the steel shells is only part of the construction operation. After the shells are driven:

- inspect the interior of each shell thoroughly:
  - by using the light that must be provided by the contractor, and
  - seeing that there are no kinks, dents, water, or other foreign material in the shell;

- inspect the reinforcement, including:
  - the sizes, lengths, spacings, splices, dimensions, or other requirements before installation into the shell, and
  - the in-place clearances after installation; and
- inspect the concrete as for other structures, including:
  - the use of an approved tube or pipe,
  - placement in layers of 24 inches or less in depth, and
  - proper consolidation of each layer.

Drilled Shaft Foundations

Although drilled shaft foundations are functionally similar to pilings (particularly cast-in-place concrete piles), they are a specifically different type of foundation constructed in three basic steps:

1. drilling the shaft,
2. installing reinforcement, and
3. placing concrete.

Drilling Operations

During drilling operations for drilled shaft foundations, you must see that each shaft is:

- properly located, with the top center within 5% of the shaft diameter, not to exceed 3 inches from the plan location;
- with 1.5 percent of a true vertical alignment; and
- drilled to the dimensions specified on the plans, including:
  - the diameter and depth, and
  - any bells or rock sockets that may be required
- in the same types of soils as shown in the boring logs.

The contractor is responsible for protecting against cave-ins from the sides of the drilled shafts during drilling – and until the concrete is placed. If caving-in is encountered, the contractor must propose a suitable method for controlling such conditions. Metal casings and slurry drilling are two commonly used methods for controlling cave-ins, but any method must be approved by the Engineer. Both metal casings and slurry drilling are governed by their own special requirements.

Each drilled shaft must be inspected before the reinforcement and concrete can be placed. See that:

- the contractor provides an adequate means of visually inspecting the full depth of the shaft;[2]
- the shaft meets the minimum dimensions specified by the plans;
- the shaft is properly aligned;
- any material is removed from the bottom of the shaft before any reinforcement or concrete is placed; and
- the drilled shafts are covered for safety, if they are not filled with concrete the same day they are drilled.

Reinforcement Installation

The reinforcing steel for drilled shaft foundations must be pre-assembled outside the shaft and are installed in the shaft immediately prior to concrete placement. Do the following:

- check the sizes, lengths, dimensions, spacing, splice staggering, splices, wire ties, etc., before the cages are placed in the shaft;
- make sure that the cages are securely tied to prevent racking or twisting during handling and ensure proper placement and size of the inspection tubes; and
- see that each cage is properly installed in its shaft, with:
  - approved spacers to provide adequate support along the sides of the shaft,
  - care to avoid dislodging loose material from the sides of the shaft,
  - the proper minimum clearances between the steel and the sides of the shaft, and
  - adequate support and anchoring of the cage to hold it securely in the correct position during concrete placement and for at least 4 hours thereafter.

Concrete Placement

The concrete for a drilled shaft foundation should be placed in the shaft as soon as possible after drilling and reinforcement installation are completed. Concrete placement requirements for drilled shafts are generally the same as for other structures.

Find out in advance how the contractor plans to place and consolidate the concrete. If there are any doubts as to the acceptability of the methods, they must be approved by the Engineer before the pour begins.[3]

- Ensure that each shaft is filled in a continuous monolithic pour;
- Ensure the rate of concrete placement is at least 40 feet per hour, and
- Ensure that the upper 10 feet of the shaft is vibrated.

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[2] The *Standard Specifications* call for "suitable equipment" to inspect the shaft. In sunny weather a mirror or shiny metal surface may be adequate to reflect enough sunlight into the shaft. Under other conditions, artificial lighting may be needed.

[3] The *Standard Specifications*, Section 609 on Drilled Shaft Foundations, refers to Section 601 on Concrete Structures for concrete placement. This implies the need to place the mix in layers and consolidate each layer. However, this is rarely possible due to the depth and limited access of drilled shafts. It is generally argued that the higher slump of the mix, the weight of the mix in the upper part or the shaft, and the permanent containment provides sufficiently dense concrete so that only the upper 10 feet which can be reached with a vibrator need consolidation.

If a metal casing has been used to control caving conditions to seal off water or drilling fluids:

- it should remain in place only when so specified by the plans, or
- if removed, it must be gradually removed in conjunction with concrete placement, so that:
  - a head of concrete not less than 10 feet is maintained above the bottom of the casing in a dry cased hole;
  - a head of concrete is maintained a minimum 5 feet above the water table or drilling fluid level on the outside of the casing; and
  - care is taken to avoid dislodging or shifting of the steel.

If water is present in an uncased hole, or slurry has been used to control caving conditions the concrete shall be placed by pumping using approved pumping equipment. The key points to watch for are:

- the slump of the concrete mix shall be 8" ± an inch unless otherwise specified;
- the use of an approved type of tube or tremie to minimize segregation of the mix;
- care shall be taken to ensure that all the fluid and suspended solids are expelled from the hole during concrete placement; and
- the top 5 feet of the shaft shall be vibrated after the slurry or water and contaminated concrete has been totally expelled from the shaft;
- the lower end of the pump pipe shall be provided with a valve or plug, when lowered into the slurry, to prevent contamination of the concrete;
- pumping shall begin when the pipe is 6 inches above the bottom of the hole;
- the discharge end of the pump pipe shall always remain between one and three diameters of the drilled shaft below the surface of fluid concrete; and
- ensure adequate concrete on the project site before beginning placement.

Section Two Quiz

1. In structural excavation for a bridge footing, the “neat line” must ... (Circle one or more)
   a. provide adequate space for forms and workers outside the footing.
   b. be sloped or braced as needed for safety.
   c. be at or below the planned elevation for the bottom of the footing.
   d. be at or above the planned elevation for the bottom of the footing.
   e. be firm, uniform and level.

Optional 2. Which of the following types of pile-driving hammers may be used for steel H-piles? (Circle one or more)
   a. a single-action, diesel-powered hammer with a capacity of 18,000 foot-pounds per blow
   b. a gravity hammer weighing 8,000 pounds
   c. a double-action, air-powered hammer with a capacity of 12,000 foot-pounds per blow

Optional 3. Which of the following aspects of preparing for pile driving would usually **not** apply to steel shells for cast-in-place concrete piles? (Circle one or more)
   a. seeing that the shells are handled only at the designated lifting points
   b. embankment construction
   c. checking and recording heat numbers
   d. seeing that the shells are fitted with enclosed driving tips
   e. pre-drilling holes at each pile location

Optional 4. At the start of pile-driving operations, your primary inspection concern should be ... (Circle one)
   a. the correct vertical or battered alignment.
   b. the initial rate of penetration.
   c. calculating the initial bearing value.

Optional 5. If the plans specify only a minimum bearing value (with no tip elevation requirement), you should ... (Circle one)
   a. calculate and document the bearing values, without monitoring or recording the piles penetration.
   b. monitor both the penetration and bearing values, but only record the bearing values.
   c. monitor and record both the penetration and bearing value.

Optional 6. Using the appropriate formula from page 20, calculate the bearing value of a steel H-pile being driven by a single-action diesel hammer, if:

- the weight of the hammer is 8,000 pounds,
- the stroke of the hammer is 5 feet, and
- the pile penetrates l.5 inches in 10 consecutive blows.

Bearing value = _______________ tons

7. In constructing drilled shaft foundations, which of the following practices should **not** be allowed unless specified in the plans or specifically authorized by the Engineer? (Circle one or more)

   a. drilling the shaft 2 inches wider than the planned diameter
   b. removing the metal casing as the concrete is placed
   c. using slurry to control caving conditions
   d. raising the bottom elevation of the shaft 2 feet higher than planned to avoid unstable material

8. Which of the following aspects of the reinforcing steel for drilled shafts must be checked before the steel is installed in the shaft? (Circle one or more)

   a. bar sizes and dimensions
   b. wire ties
   c. steel clearances
   d. bar spacings

Section Two Quiz Answers

1. c. be at or below the planned elevation for the bottom of the footing.
   e. be firm, uniform and level.

2. a a single-action diesel-powered hammer with a capacity of 18,000 foot-pounds per blow

3. a. seeing that the shells are handled only at designated lifting points
   c. pre-drilling holes at each pile location

4. a. the correct vertical or bartered alignment.

5. c. monitor and record both the penetration and bearing value.

6. Bearing value = <u>160</u> tons.

$$P = \frac{2WH}{S + 0.1} = \frac{2(800)(5)}{0.15 + 0.1} = \frac{80{,}000}{0.25} = 320{,}000\,\text{lbs.} = 160\ \text{tons}$$

7. c. using slurry to control caving conditions
   d. raising the bottom elevation of the shaft 2 feet higher than planned to avoid unstable material

8. a. bar sizes and dimensions
   b. wire ties
   d. bars spacings

Notes

Third Discussion Period
(Substructure Construction)

Section Three: Substructure Construction

Parts of the Substructure

The substructure for any bridge consists primarily of its piers and abutments. Because these are predominantly constructed with concrete, most of the construction methods and requirements for bridge substructures are the same as for smaller incidental concrete structures.

However, depending on the specific design of the bridge, its piers and abutments usually include a wide variety of such parts as:

- footings, pilings, or drilled shafts as foundational supports;
- columns or solid walls as vertical supports;
- pier caps, cap beams, or caps as the horizontal supports on which the superstructure will rest; and
- wingwalls, retaining walls, and slope pavement to help maintain the area around the abutments.

This section covers bridge substructure construction in terms of:

- reviewing the basic concrete construction methods as they apply to bridge piers and abutments; and
- summarizing certain key considerations for each of the various parts of bridge substructures.

Review of Concrete Construction Methods

The following pages review the basic methods and requirements for concrete construction as they relate to bridge piers, abutments, and other parts of the substructure.

Alignment and Grade Controls

The alignment and grade controls for bridge piers and abutments must be checked (as for any concrete structure) for:

- adequate stakes for structural locations and offset reference points;
- adequate information for each stake;
- proper identification and protection of stakes; and
- correct structural lines, grades, angles, and dimensions in accordance with the plans.

Due to the relative complexity of bridges, it is also usually necessary to periodically re-check, replace or supplement the initial controls as substructure work progresses. It is particularly important to see that the plan elevations are accurately set at such locations as:

- the tops of footings,
- the beam seats at the top of the pier and abutment caps, and
- any construction joints for which a specified elevation is shown on the plans.

Remember to re-check alignments, as well as elevations, from the footings on up. Bridges are too large and expensive to wait until the superstructure is constructed to discover that a pier or abutment is in the wrong location.

Reinforcing Steel

Although the reinforcing steel for bridge piers and abutments is generally more extensive and complex than for smaller incidental structures, it must be checked thoroughly with the plans for:

- the correct sizes, lengths, grades and shapes;
- accurate positions and spacings;
- secure splices, check length of splice, the splice/stagger and wire ties;
- firm, approved supports at the bottom and sides;
- adequate clearances from the foundation or bottom forms, the side forms and the top surface of the concrete; and
- adequate clearance surrounding all re-bar, especially at splice locations.

Some special considerations for the steel in bridge piers and abutments are summarized below:

- The planned quantities and positioning of reinforcing steel in bridge piers and abutments are particularly critical to the load-bearing needs of bridges – so check them <u>closely</u>.
- You may encounter a wide variety of different types of reinforcing steel, such as:
  - ➢ non-deformed wire spirals (for round columns), epoxy coated, rebar; and,
  - ➢ welded-wire mesh (for slope pavement and precast retaining wall panels).
- Make certain that the reinforcement extends through construction joints in accordance with the plans since it is critical to the strength of the joints.
- Remember that the large quantities and complexity of reinforcement in bridges require more <u>time</u> for thorough inspection before the concrete is poured.

Forms and Falsework

As for any concrete structure, the forms for bridge piers and abutments must be checked for such standard forming requirements as:

- planned location and dimensions;
- mortar-tight form joints;
- clean, uniform form faces;
- treatment with an approved form-release agent;
- proper alignment of special surface treatments such as rustication;
- adequate support, including:
  - ➢ snap ties, tie rods, and other internal supports, and
  - ➢ studs, whalers, braces, and other external supports; and
- blockouts, drains, and conduit locations.

In bridge substructure construction, falsework is often needed to support the forms for pier and abutment caps. As for other falsework, it must be checked for:

- lumber in good condition;
- a solid footing with uniform bearing;
- the use of wedges, screws, or jacks to firmly support the forms at the required grade;
- proper application of any wedges in pairs to ensure uniform bearing;
- provision of tell-tales to show the amount of any falsework settlement during concrete placement; and
- proper type and grade.

The key considerations for forms and falsework for bridge substructures are:

- that the contractor must submit detailed drawings of his proposed falsework design for the Engineer's approval – so you should see that all forms and falsework are constructed in accordance with the approved drawings, including the size and number of ties, nails, timber sizes, and spacing;
- that the large volume of concrete involved in constructing the substructure – particularly in vertical columns and walls – create considerable pressure that requires special attention to:
  - ➢ the rigidity of the forms,
  - ➢ mortar-tight form joints, and
  - ➢ strong, firm form supports and falsework;

- that special materials, such as molded fiberglass and Styrofoam, are often used to form special surface treatments, such as rustication;
- bracing needs to go up at the same time as the falsework; and
- pour certification issued by the contractor's professional engineer before any concrete is placed on falsework.

Concrete Placement

The placement of concrete for bridge piers and abutments is also governed by the same basic requirements as for other structures, such as:

- weather and temperature requirements, including:
  - ➢ no rain that would wash or flow the concrete,
  - ➢ a concrete temperature between 50° and 90° F, and
  - ➢ special considerations for hot or cold weather;
- pre-pour preparations, including:
  - ➢ checking steel and forms thoroughly,
  - ➢ ensuring adequate labor and equipment to work the concrete,
  - ➢ wetting the forms just prior to concrete placement, and
  - ➢ all trash and debris are removed from the forms;
- cleaning and mix delivery requirements, including:
  - ➢ collecting the delivery ticket for each load,
  - ➢ seeing that each load is within the specified time limits,
  - ➢ sampling and testing the mix at the required frequency for concrete temperature and slump,
  - ➢ checking proper mix design number on batch ticket, and;
- proper placement and consolidation of the mix, including:
  - ➢ seeing that it is not dropped more than 8 feet, without an approved tremie pipe or tube,
  - ➢ placement at or near its final position,
  - ➢ placement in layers of 24 inches or less,
  - ➢ consolidation of each layer, and
  - ➢ proper operation of vibrators.

Due primarily to the large volumes of mix involved and the monolithic nature of most bridge pours:

- the contractor must be able to achieve a minimum production rate of 35 cubic yards per hour;
- various types of buckets, tubes or other equipment are usually needed to convey the concrete mix from the trucks to the forms; and
- you should pay special attention to:
  - ➢ resources for the pour – including standby equipment,

  - proper placement of the mix to avoid segregation, and
  - proper layering and consolidation of the mix to avoid honeycombing and cold joints – particularly in vertical columns or walls; and

- check contractors placement equipment (vibrators).

Pumping is often used to convey the mix to the forms. When pumping is used, you should specifically ensure that:

- the pumping equipment meets all requirements,
- the material used to prime the pump is <u>not</u> placed in the structure,
- the pump provides continuous stream of mix, without air pockets voids or segregation,
- standby pumping equipment is readily available, and
- the equipment is flushed after each use.

Because some bridges span rivers or other drainage channels, you also may encounter the need to place concrete under water. This situation is commonly called "tremie" concrete. Ensure that:

- concrete is placed under water <u>only</u> when specifically designated in the plans or approved by the Engineer;
- the basic mix design has been properly adjusted for underwater placement;
- the forms are water tight;
- an approved type of pipe or tube is used so that the mix does not fall through the water;
- a head of concrete is maintained above the discharge end of the pipe or tube and additionally above the level of the surrounding water so the water is forced up and out; and
- the concrete is <u>not</u> vibrated or otherwise disturbed after it is deposited (which would cause the water to mix with the concrete).

Finishing Exposed Surfaces

As for any other concrete structure, the top, unformed surfaces of footings and caps must be properly finished:

- by striking off the concrete with a screed or strike-off board at the specified elevations,
- with a uniform surface, and
- to a smooth finish.

Concrete Joints

Construction joints are particularly critical to the strength of bridge piers and abutments. They are typically horizontal joints located between:

- footings and columns or walls,
- columns or walls and caps, and
- abutment caps and backwalls.

Ensure that construction joints in bridge substructures are:

- constructed only at locations specifically required or allowed on the plans;
- finished with a rough, keyed surface;
- cleaned free of laitance or curing compound from the previous pour by means of:
  - ➢ air and water jets, if less than 8 hours after the previous pour, or
  - ➢ sand blasting, if 8 or more hours have passed;
- properly formed with tight forms;
- properly reinforced; and
- thoroughly saturated with water just before concrete placement.

Expansion joints in bridge substructures are typically vertical joints at such locations as between abutment backwalls and wingwalls. For both expansion joints and waterstops, see that they:

- are located in accordance with the plans, and
- are constructed with the correct types of materials and dimensions.

Curing

The curing of bridge substructural elements must meet the same basic requirements as for other structures, including:

- the total curing time of at least:
  - ➢ 7 days for most concrete, or
  - ➢ 3 days, if rapid-cure cement is used; and
- proper use of one or more of the following methods:
  - ➢ forms in-place curing for formed surfaces (until stripped for finishing),
  - ➢ curing compound for unformed surfaces (and for formed surfaces after finishing), or
  - ➢ water curing (permissible, but rarely used).

Removal of Forms and Falsework

As for any other structure, the forms and falsework for piers and abutments must:

- remain in place until removal is authorized by the Project Engineer, and
- be removed without damage to the structure.

Generally, the side forms for footings, walls, columns, and caps can be removed a day or two after the pour, so that finishing work can be done while the concrete is still "green." However, the falsework for the bottom forms of a pier or abutment cap must remain in place:

- for at least 10 days and until at least 70 percent of the required 28-day comprehensive strength has been attained,

  OR

- for at least 5 days and until the full 28-day compressive strength is achieved.

Finishing Formed Surfaces

All formed concrete surfaces of the substructure, whether above or below grade, must receive at least a Class I finish, including:

- removing or recessing (at least one inch) all ties immediately after forms are removed;
- cleaning and moistening all holes, recesses, honeycombed areas, etc.; and
- spot-patching these areas with mortar, including curing the mortar.

Those formed surfaces that will be visible to the public must receive a Class II finish, including:

- removing ties, cleaning and patching as for a Class I finish;
- rubbing the surface to produce a uniform surface;
- brushing or sacking the surface when a light dust appears; and
- achieving a smooth surface with uniform color, but without creating a plaster coating.

Backfill

For backfilling around bridge footings, walls and columns, ensure that:

- the full design strength is achieved before backfilling begins behind abutment walls, wingwalls and cast-in-place retaining walls;
- suitable backfill material at or near optimum moisture is placed in layers of 8 inches or less; and
- each layer is uniformly compacted to at least 95 percent of the material's maximum density.

Key Considerations

Although the basic concrete construction methods for bridge piers and abutments are the same as for other structures, there are certain aspects of each part of a bridge substructure that warrant special consideration.

Footings

For bridge footings, you should see that:

- they rest on a firm, uniform foundation;
- any pilings or steel from drilled shafts are properly embedded and anchored;
- the top of each footing is struck-off with a screed or strike-board to the correct elevation; and
- each footing meets the standard dimensional tolerances of:
  - between minus- ½-inch and plus- 2-inch for cross-sectional dimensions, and
  - minus 5 percent of the planned thickness up to a maximum of minus-1-inch

Vertical Columns and Walls[4]

Columns and walls in piers and abutments require special attention due to their vertical nature and load-bearing function. The key points to watch for are:

- adequate clearances and firm support for the reinforcement (which is particularly critical to the strength of the column or wall);
- continuous, monolithic placement of the concrete, such that:
  - the mix is properly layered and consolidated throughout the pour,
  - cold joints are avoided, and
  - construction joints are formed only at locations designated in the plans;
- the standard dimensional tolerances for walls and columns, including:
  - no deviation from plumb greater than ⅜-inch per 10 feet or 1 inch in the entire height, and
  - cross-sectional dimensions must be between minus-⅛-inch and plus-¼-inch of the plan dimensions.

Pier and Abutment Caps

For pier and abutment caps, you should ensure that:

- any falsework used for constructing the cap is:
  - constructed in accordance with the contractor's approved drawings, and
  - left in place through the full curing period; and

[4] Check proper installation of drainage material; also ensure drainage outlets.

- the beam or girder seats are:
  - ➢ struck-off and finished to the correct, specified elevations, and
  - ➢ finished to standard dimensional tolerances of plus-¼-inch and minus-⅛-inch from the required elevation, and
  - ➢ provided with the necessary cable restraints, bearing plate anchor bolts, or other features as may be specified by the plans to anchor the superstructure.

Retaining Walls and Wingwalls[5]

Although retaining walls and wingwalls do not carry the vertical load carried by pier or abutment walls, their vertical nature requires attention to the same key considerations as for pier and abutment walls. Additionally, you should pay special attention to:

- the casting, erection, foundation and anchorage for precast panels when this approach is used; and

- backfilling operations to see that the wall is not damaged or displaced.

Slope Pavement

When slope pavement is used to control erosion around abutments, see that:

- the appropriate methods are used for the specified type of material or surface treatment, which may include:
  - ➢ concrete or Shotcrete, and
  - ➢ an exposed aggregate finish or other surface treatment; and

- all joints properly located and constructed to control cracking.

[5] Check proper installation of drainage material; also ensure drainage outlets.

Section Three Quiz

1. Which of the following substructure parts does **not** bear the vertical load of the superstructure? (Circle one or more)

   a. an abutment wingwall
   b. a pier footing
   c. an abutment cap
   d. pier columns
   e. an abutment wall
   f. slope pavement

2. At which of the following locations is it particularly critical that grade controls be re-checked to ensure accurate elevations in accordance with the plans? (Circle one or more)

   a. bottom of a footing excavation
   b. top of a footing
   c. tops of pier columns
   d. beam seats on an abutment cap
   e. top of a retaining wall

3. For which of the following substructure parts would falsework most likely to be used to support the forms? (Circle one)

   a. a spread footing
   b. cylindrical pier or abutment columns
   c. a pier cap
   d. an abutment wingwall

4. Which of the following requirements for concrete placement is applicable to all <u>major</u> structures but **not** required for most smaller, incidental structures? (Circle one or more)

   a. a concrete temperature of between 50° F and 90° F
   b. sufficient resources to achieve a rate of at least 35 cubic yards per hour
   c. placing concrete in layers of 24 inches or less in depth
   d. using vibrators to consolidate the mix

5. For which of the following situations (if any) would extra, standby vibrators **not** be needed? (Circle one or more)

   a. pouring a pier cap
   b. pouring a series of pier columns
   c. pumping concrete into an abutment wall
   d. placing tremie concrete for a submerged footing
   e. none of the above – vibrators and standby vibrators are always needed

6. At which of the following locations would construction joints usually be allowed in a typical bridge pier? (Circle one or more)

   a. as a vertical joint in the middle of a wide spread footing
   b. between a pier column and its footing
   c. as a horizontal joint in the middle of a pier column
   d. between each pier column and the pier cap
   e. wherever the contractor stops concrete placement at the end of each day’s operations

7. When forms-in-place curing is used, ... (Circle one or more)

   a. all side forms must remain in place for at least 7 days.
   b. side forms may be removed the next day only for purposes of early backfilling.
   c. side forms are often removed the next day in order to facilitate finishing operations.

8. When falsework is used to support the forms for part of a bridge’s substructure it may be released and removed after at least ... (Circle one or more)

   a. 24 hours, if curing compound is applied.
   b. 3 days, if water curing is used.
   c. 10 days, if 70% of the 28-day strength is attained.
   d. 15 days, if the full 28-day strength is attained.
   e. 5 days if the full 28-day strength is attained.
   f. 5 days, if 50% of the 28-day strength is attained.

9. Under which of the following conditions may backfill be placed behind abutment walls, wingwalls, or retaining walls? (Circle one or more)

   a. as soon as possible after Class I finishing is completed
   b. after the 7-day curing period
   c. after 28 days
   d. after the full 28-day design strength is attained

Section Three Quiz Answers

1. a. an abutment wingwall
   f. slope pavement

2 b. top of a footing
  d. beam seats on an abutment cap
  c. tops of pier columns

3. c. a pier cap

4. b. sufficient resources to achieve a rate of at least 35 cubic yards per hour

5. d. placing tremie concrete for a submerged footing

6 b. between a pier column and its footing
  between each pier column and the pier cap

7. a all side forms must remain in place for at least 7 days.

8. c. 10 days, if 70% of the 28-day strength is attained.
   e. 5 days, if the full 28-day strength is attained.

9. d. after the full 28-day strength is attained

Notes

Fourth Discussion Period
(Beams and Girders)

Section Four: Beams And Girders

Basic Information

The basic function of a bridge's beams or girders is to form the spans between piers and abutments in order to support the bridge deck. Although there are several different types of beams and girders, there are also several key aspects of their parts and terminology which generally apply to all types.

Types of Beams and Girders

All types of bridge beams and girders generally can be categorized into two basic groups:

1. those that are prefabricated and erected into place, including such types as:
   - steel girders,
   - precast concrete I-beams, and
   - precast concrete box beams; and
2. those that are constructed in-place, including such types as:
   - cast-in-place concrete box girders, and
   - cast-in-place continuous slab.[6]

As previously discussed (in Section One), the more common of these types are steel girders, precast concrete I-beams, and cast-in-place box girders.

Key Aspects of Beams and Girders

The various types of beams and girders generally share certain key characteristics, including bearing points, diaphragms and deflection.

Bearing points are the points at which the ends of a beam or girder rest on the piers and abutments, as illustrated on page 44. Usually, some type of bearing pad or plate assembly is placed between the beam or girder and the top of the pier or abutment. Generally, this bearing device may be either:

- a **fixed** type of bearing that allows the beam to only rotate, or
- an **expansion** type that permits some slight longitudinal movement.

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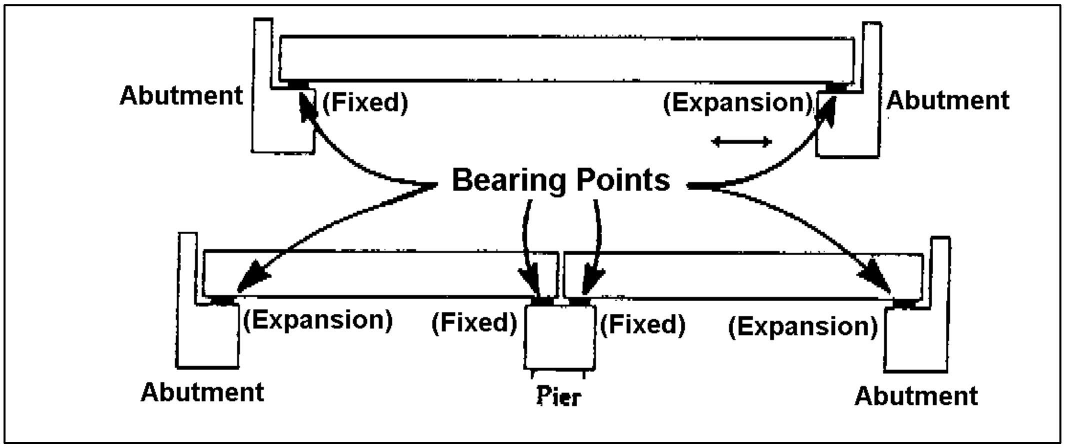
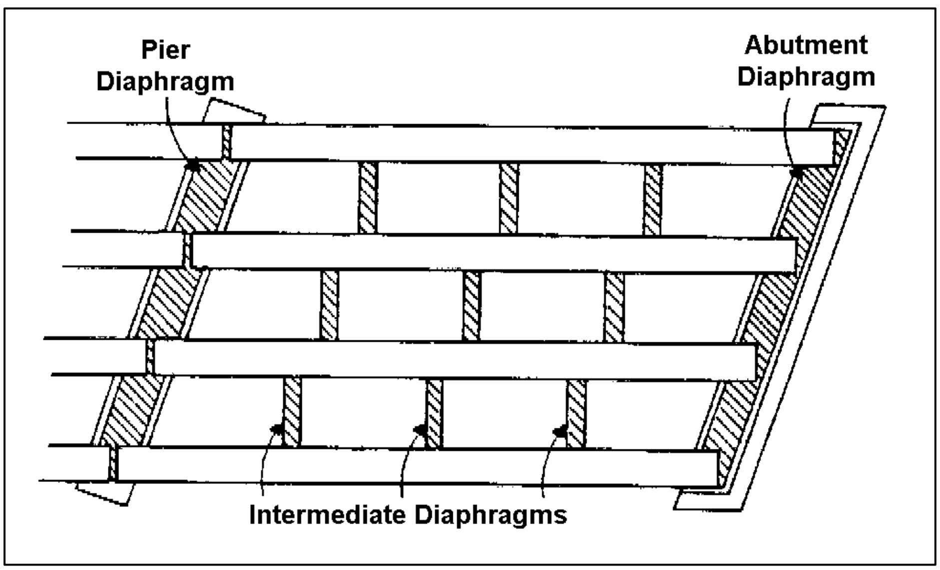
[6] Cast-in-place continuous slab type incorporates the function of beams and girders into a thicker deck slab, which rests directly on the piers and abutments.

As a general rule, one end of any span is designed as a fixed bearing while the other end provides for expansion, as shown below.

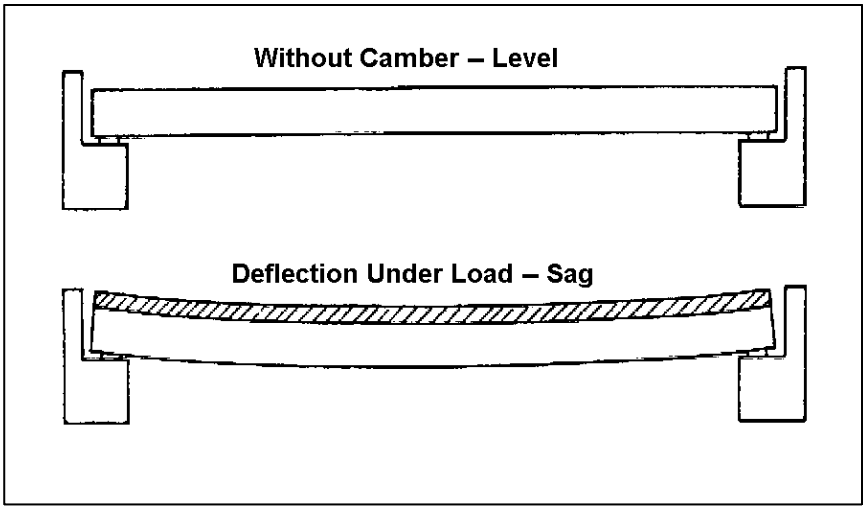


Diaphragms provide the beams or girders with lateral support. As shown in the plan view drawing below, they include:

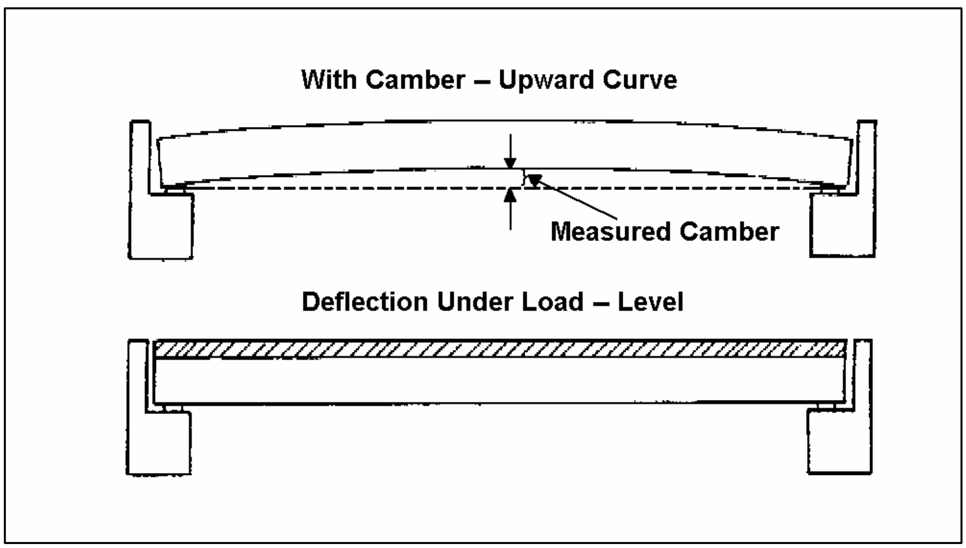
- pier and abutment diaphragms, and
- intermediate diaphragms.



Camber and **deflection** also must be considered in the design and construction of bridge beams and girders. If a beam or girder is fabricated so that it is exactly straight and level, the weight of the diaphragms, deck, and other parts of the superstructure will **deflect** it so that it sags in the middle.



Most beams and girders (particularly those that are prefabricated and erected into place) are designed and fabricated with some ***camber*** or upward curvature. This camber provides allowance for the weight of the superstructure so that the beam deflects into the desired position under the load.



Steel Girders

(Optional Reading)

The erection and inspection of steel girders includes four primary steps:

1. preparing the beam seats and bearing devices,
2. delivering the materials,
3. erecting the girders and diaphragms, and
4. tightening the bolts.

Preparing the Girder Seats

Steel girders are typically set on metal bearing plate assemblies. The lower part of the assembly is usually anchored to the girder seat, while the upper portion is bolted to the bottom of the girder. The design of the connecting area between these two parts will vary depending on whether the bearing device is a fixed or expansion type.

Before the girders are erected, you should inspect the girder seats and bearing devices closely to see that:

- the girder seats are properly prepared in accordance with the plans, with particular attention to:
  - the correct elevation of each seat (+ ¼", -⅛"*)*,
  - the exact position and dimensions of any embedded anchor bolts or pins,
  - the girder seats are checked for flatness (±⅛-inch in 10 ft); and
- the bearing devices are properly set with:
  - the correct fixed or expansion type and dimensions, and
  - the proper alignment and grade.

Delivery of the Materials

As the girders, diaphragms, and connecting hardware are delivered to the site, you should:

- check and record the heat numbers on the girders and diaphragms;
- make certain that a Certificate of Analysis has been submitted to cover each heat number;
- spot-check the dimensions of the girders, diaphragms, and other hardware in relation to the plans and shop drawings;
- inspect the steel for any excessive rust, bends, faulty welding or bolting, or other defects; and
- see that all materials are properly stored and handled, including:
  - keeping large, cambered girders in an upright position, and
  - storing all steel materials in a manner that will avoid mud or water that could cause rusting.

Erecting Girders and Diaphragms

For steel girder bridges, each prefabricated girder and diaphragm member is usually pre-numbered to identify its exact position within the bridge. The main, longitudinal girders are usually erected first and then followed by the diaphragms.

As steel girders and diaphragms are erected, see that:

- each member is properly handled to avoid damaging the member or its shop-coat of paint;
- each girder is fully and accurately seated on the bearing device at each end of the span;
- particularly large or top-heavy girders are adequately braced or restrained for temporary support until the diaphragm can be erected; and
- sufficient temporary bolts or other connectors are placed to provide adequate support until all members of the span are set into position.

Final Bolting

High-strength bolts are the most commonly used method for connecting steel girders and diaphragms.[7] You should inspect the final tightening of the bolts to see that:

- final tightening is done after all girders and diaphragms within the span are correctly positioned;
- all bolts, nuts, washers and other connecting hardware comply with the types, grades, and dimensions specified in the plans;
- all bolts, nuts, washers, and other connecting hardware are properly lubricated and free of rust or dirt;
- the areas under the connection plates are free of any paint or foreign material;
- all bolt holes in the girders, diaphragms and connection plates are properly aligned;
- the friction area around each bolt hole is free of loose scale, dirt or other foreign material;
- all bolts are tightened following the tightening sequence specified in the plans or shop drawings, in terms of:
  - ➢ the overall sequence, and
  - ➢ the sequence of individual bolts at each connection (usually from the center out);

  and
- each bolt is properly tightened in accordance with the plans or shop drawings to either:
  - ➢ a specified tension (kips) using a properly calibrated torque wrench,
  - ➢ a specified number of turns, or
  - ➢ to the specific load using direct tension indicator washers or breakaway bolts.

[7] Although such other methods as welding and riveting are less commonly used today, they are still permitted, so check the plans for the specified type of connections.

Precast Concrete Beams

The erection and inspection of precast concrete beams also include four basic steps:

1. camber the beam seat and bearing devices,
2. delivering and handling the beams,
3. erecting the beams, and
4. constructing the diaphragms.

Preparing the Beam Seats

Precast concrete beams are typically placed on elastomeric or fabric bearing pads. The extent to which the bearing point is a fixed or expansion type generally depends on the specific design of the cap, beams, and diaphragm, including such features as:

- anchor plates embedded in the beam seats and bottoms of the beam ends,
- cable restrainers that anchor the diaphragm to the cap,
- shear keys formed in the top of the cap between the beam seats, and
- various joint materials used between the cap and diaphragm.

To inspect the beam seats before the beams are erected, see that:

- the cap has been constructed in accordance with the plans, with particular attention to such details as:
  - the correct elevation of each beam seat,
  - the proper types, dimensions and positions of such embedded items as anchor plates and cable restrainers, and
  - the correct dimensions and positions of any transverse or longitudinal shear keys; and
- the bearing pads are properly set, including:
  - the specified type and dimensions, and
  - the correct position and alignment.

Delivery and Handling of Materials

As precast concrete beams are delivered to the site for erection, you should:

- see that they are transported and stored:
  - in an upright position, and
  - with supports at or near the final bearing points;
- be sure that each precast beam is covered by an ADOT stamp and a Certificate of Compliance;

- inspect the beams in relation to the plans and shop drawings in terms of:
  - their overall dimensions, alignment and camber, and
  - such features as re-bar (stirrup) extensions, threaded inserts, and lifting devices;
  - watch for any cracks, exposed steel or other defects of damage to the beams; and
  - see that they are lifted only by the specified lifting devices.

Erecting Precast Concrete Beams

As precast beams are erected, your primary inspection concerns are to see that they are:

- properly handled to avoid damage to the beams themselves – or their surroundings;
- each beam is set in its proper location; and
- accurately seated into the correct position.

Constructing Diaphragms

The diaphragms for precast concrete I-beams also are made of concrete, but are cast-in-place after the beams are erected. The intermediate diaphragms are usually constructed first, while the pier or abutment diaphragms are typically poured in conjunction with the deck.

For the intermediate diaphragms, see that:

- they are constructed as soon as possible after the beams are erected, so that they provide lateral support;
- falsework hangers and forms are constructed in accordance with the approved drawings;
- all threaded rods and reinforcing steel are set in accordance with the plans;
- thoroughly saturate forms with water just prior to concrete placement; and
- the concrete is properly placed, consolidated, finished and cured as for any other structure.

For the pier and abutment diaphragms, you also should pay particular attention to such features as:

- any joint filler, polystyrene hardboard, or other joint materials required between the cap and diaphragm; and
- securely positioning the upper portion of cable restrainers, along with the reinforcement.

Cast-in-Place Box Girders

The construction of cast-in-place concrete box girders usually involves five basic stages of operation:

1. preparing the soffit fill or other type of falsework;
2. constructing the bottom slab, girder walls, and diaphragm walls;
3. constructing the bridge deck, as the top slab of the boxes;
4. post-tensioning (when required); and
5. removing the soffit fill or other falsework.

Falsework Preparations

Since virtually the entire superstructure of a concrete box girder bridge is cast in place, extensive falsework is needed to support each span until it can support itself. The contractor is responsible for designing the type of falsework to be used, but the most typical approach is a "soffit fill," in which:

- the piers and abutments are first constructed as for any other bridge,
- a temporary earthen fill is then constructed to fill in the space under each span, and
- finally, a waste slab is poured as the forming face for the bottom of the superstructure.

During preparation of a soffit fill, you must see that:

- all elements of the fill are constructed in accordance with the contractor's approved falsework plan;
- the finished surfaces of the piers and abutments are adequately protected with Styrofoam, plastic, or other materials as they are buried in the fill;
- the temporary fill is constructed in basically the same manner as a permanent embankment, including:
    - placing the fill materials in uniform layers,
    - compacting each layer, and
    - testing the density of the fill as it is constructed;
- the top of the fill is adequately finegraded to the elevations needed for the bottom of the waste slab; and
- the waste slab is properly formed, poured and finished (usually with deck-finishing equipment) to provide a uniform surface at the **exact** elevations required for the bottom of the box girders.

Bottom Slab and Walls Construction

The bottom and walls – including the girder walls and diaphragm walls – are then constructed on the waste slab. In a typical box girder bridge, this includes:

1. marking the layout of the girder, diaphragms, and bottom steel on the waste slab;
2. preparing the bearing areas at the piers and abutments, including:
   - expansion bearings (usually at the abutments) with bearing pads, joint filler, and other materials such as polystyrene and hardboard, and
   - fixed bearings (usually at the piers) which is often simply reinforced construction joints;
3. setting the exterior forms, including:
   - the steel for the bottom slab,
   - the steel and post-tensioning ducts for the girders, and
   - the steel for the diaphragms;
4. setting the interior forms for the girders, pier diaphragms, and abutment diaphragms;
5. pouring and curing the bottom slab, girders, pier diaphragms and abutment diaphragms; and
6. forming, pouring, and curing the intermediate diaphragms.

During construction of the bottom slab and walls, you should:

- see that an adequate amount of bond breaker is applied to the waste slab after the layout markings are completed (to minimize discoloration of the bottom of the superstructure);
- see that the pier and abutment bearing seats are prepared in accordance with the plans;
- check the exterior side forms for such key aspects as:
  - ➢ using new plywood (for the Class II finish),
  - ➢ the proper batter, and
  - ➢ adequate support;
- check the exterior end forms with particular attention to:
  - ➢ the block-outs for the post-tensioning ducts, and
  - ➢ particularly the angle of the block-out forms at the post-tensioning bearing plates (which must be 90° to the line of the cable);
- check the placement of the reinforcing steel thoroughly as for any other structure;
- check the post-tensioning ducts for:
  - ➢ compliance with the approved shop drawings, including the proper type, size, and position,
  - ➢ uniform alignment and transition,
  - ➢ mortar-tight joints,
  - ➢ any kinks, dents or holes in the ducts,

- ➢ adequate ties and supports to hold the duct work firmly in place, and
  - ➢ any conflicts between the planned re-bar and duct positions (and contact Structures Division if such conflicts arise);

- check the interior forms for the girder and diaphragm walls, with particular attention to such features as:

  - ➢ adequate support and clearance at the bottom of the forms with approved blocks or chairs,
  - ➢ re-bar clearances,
  - ➢ proper positioning of snap-tie supports to avoid any conflict with the post-tensioning ducts, and
  - ➢ block-outs for drain holes, utility conduits or other miscellaneous items;

- inspect the concrete placement as for other structures – but with particular attention to:

  - ➢ the pour sequence as specified in the plans,
  - ➢ adequate resources (including standby equipment) for the pour;
  - ➢ seeing that the bottom slab and walls are poured progressively so that mix in the walls does not push out into the bottom – but without creating cold joints;
  - ➢ placing and vibrating mix around and under the ducts to see that the hard-to-get areas are filled – but without damaging or shifting the ducts; and
  - ➢ make a pour diagram of location concrete is placed (every 50 cubic yards) and

- see that the concrete construction is properly completed as for other structures, including:

  - ➢ curing the concrete,
  - ➢ removing the forms, and
  - ➢ finishing (Class I) the formed surface.

Deck Construction

The Construction of the deck for a box girder bridge is generally the same as for other bridges (as is discussed in Section Five). However, there are a few key points that you should watch for in box girder deck construction.

Because the interior deck forms and falsework for a box girder bridge must remain permanently in place, see that:

- any falsework or form supports that bear on the bottom slab are within 10 inches of the girder walls (hangers that bear directly on the girders are most commonly used), and

- the cells are cleaned out before the forms are set.

For post-tensioned box girders, you should also see that the ducts are tested before the deck is poured, including:

- testing the internal dimensions of each duct to ensure adequate clearance for the cables, and
- pressure-testing each duct to be sure that it will hold the grout after post-tensioning.

Post-Tensioning

Post-tensioning is a highly specialized task that often requires a specifically experienced and qualified inspector. However, even with a specialized inspector to assist you, you must still be aware of certain basic procedures and requirements involved in post-tensioning. Before the post-tension can begin:

- the deck must:
  - be cured for at least 7 days, and
  - achieve the required strength for jacking;
- the prestressing cables must be installed, including:
  - demonstrating that the ducts are free of any dirt, mud, water, or other foreign material before the cable is run,
  - keeping the cable free of water, mud, etc.
  - if installed earlier, protecting the stands against rust or other corrosion using an approved corrosion inhibitor placed in the ducts or applied to the steel in the ducts,
  - if installed earlier, demonstrating that they can still move freely;
- all exterior forms must be removed; and
- all equipment for monitoring the loads must be checked for accurate calibration.

During stressing operations:

- all personnel shall avoid the area behind the ends of the cables being tensioned at all times, (for safety), the cables must be stressed by jacking:
  - from one end for simple single spans, or
  - from each end for multiple spans;
- the stressed load must be closely monitored to the specified 20 percent and maximum loads;
- the elongation of the cable under stress must be measured;
- any seating loss must be identified as the load is transferred from the jack to the anchor; and
- the excess ends of the tensioned cable must be abrasively cut (<u>no</u> cutting torch).

After the cables are tensioned and anchored, the ducts are filled with grout by pressure grouting. This operation includes:

- preparing for grouting by:
  - cleaning the ducts of any harmful material, using oil-free compressed air,
  - installing the pressure grouting valves,
  - providing standby equipment for flushing,
  - properly mixing the grout (with no more than 5 gallons of water per 94 pounds of cement), and
  - testing the grout for its efflux-time with the flow-cone test; and
  - checking the temperature of the grout, maximum 90° F, minimum 50° F;

- pressure-grouting each duct by:
  - pressure-feeding grout through the inlet valve until it discharges through the open outlet valve at the other end,
  - leaving the outlet open until the grout flows fully with no air or water,
  - closing the outlet,
  - checking for any leaks while under pressure,
  - maintaining a minimum pressure of 75 psi for at least one minute before the inlet valve is closed, and
  - if minimum pressure can not be obtained, flush the grout out of the ducts; and
- leaving all valves closed and in place until at least the next day.

After the post-tensioning operations are completed, the rest of the superstructure can be constructed, including:

- filling in the post-tensioning block-outs, constructing the abutment backwalls, and
- forming and pouring such above-deck incidentals as curb and barrier wall.

Falsework Removal

The soffit fill – or any other type of falsework – must remain in place until after the post-tensioning operations have been completed. As the soffit fill is removed, see that:

- the waste slab and the protective covering around piers and abutments are removed without any damage to the structure, and
- the bottom of the superstructure (and any other exposed surfaces) are adequately finished to achieve a Class II finish.

Section Four Quiz

1. In a cast-in-place box girder bridge, any deck falsework or form supports that bear directly on the bottom slab must be ... (Circle one or more)
   a. about halfway between girder.
   b. at least 1 foot from the nearest girder wall.
   c. within 10 inches of the nearest girder wall.
   d. removed after the deck is poured and cured.

2. Which of the following inspection items is generally applicable to all types (steel, precast concrete and cast-in-place concrete) of beams and girders? (Circle one or more)
   a. checking the elevations of the beam or girder seats
   b. seeing that pier and abutment diaphragms are constructed in conjunction with the bridge deck
   c. inspecting the construction of the soffit fill or other falsework
   d. checking the alignment of the metal bearing plate assemblies

Optional 3. Which of the following best summarizes the overall construction sequence for steel girders? (Circle one)
   a. (1) girders, (2) bolts, (3) diaphragms, and (4) bearing devices
   b. (1) bearing devices, (2) girders, (3) bolts, and (4) diaphragms
   c. (1) bearing devices, (2) girders, (3) diaphragms, and (4) bolts
   d. (1) girders, (2) bearing devices, (3) bolts, and (4) diaphragms
   e. (1) bearing devices, (2), diaphragms, (3) girders, and (4) bolts

Optional 4. As prefabricated steel girders are delivered to the site, they should be checked for which of the following? (Circle one or more)
   a. an ADOT stamp on each girder
   b. the heat number on each girder
   c. a Certificate of Compliance
   d. a Certificate of Analysis
   e. special lifting devices at or near the bearing points

Optional 5. For which of the following types of beams and girders would a metal bearing plate assembly most likely be used? (Circle one or more)

a. steel girders

b. precast concrete I-beams

c. cast-in-place concrete box girders without post-tensioning

d. cast-in-place concrete box girders with post-tensioning

6. Which of the following practices should <u>not</u> be allowed in transporting, handling and storing a precast concrete girder? (Circle one or more)

a. transporting beams on their sides
b. lifting beams with straps or cables placed under the center of the beam
c. lifting beams by the reinforcing bars that extend above the tops of the beams to tie-in to the deck
d. storing beams with support at or near the final bearing points

7. In a precast concrete girder bridge the pier and abutment diaphragms are usually formed and poured ... (Circle one)

a. … before the intermediate diaphragms.
b. … at the same time as the intermediate diaphragms.
c. … after the intermediate diaphragms, in conjunction with the deck.

8. At which of the following locations in a box girder bridge would construction joints usually be permitted? (Circle one or more)

a. between the bottom slab and girder walls
b. between the bottom slab and the pier and abutment diaphragms
c. between the girder walls and the pier and abutment diaphragms
d. between the girder walls and the intermediate diaphragms
e. between the girder walls and the deck
f. between the pier and abutment diaphragms and the deck

9. In a post-tensioned box girder bridge, which of the following activities must be completed before the prestressing cables can be tensioned? (Circle one or more)

a. placement and curing (for at least 7 days) of the deck
b. construction of above-deck incidentals
c. pressure-testing the post-tensioning ducts
d. removing the soffit fill
e. removing the exterior side forms

Section Four Quiz Answers

1. c. … within 10 inches of the nearest girder wall.

2. a. checking the elevations of the beam or girder seats

3. c. (1) bearing devices, (2) girders, (3) diaphragms, and (4) bolts

4. b. the heat number on each girder
   d. a Certificate of Analysis

5. a. steel girders

6. a. transporting beams on their sides
   b. lifting beams with straps or cables placed under the center of the beam
   c. lifting beams by the reinforcing bars that extend above the tops of the beams to tie-in the deck

7. c. after the intermediate diaphragms, in conjunction with the deck.

8. d. between the girder walls and the intermediate diaphragms
   e. between the girder walls and the deck
   f. between the pier and abutment diaphragms and the deck

9. a. placement and curing (for at least 7 days) of the deck
   c. pressure-testing of the post-tensioning ducts
   e. removing the exterior side forms

Notes

Fifth Discussion Period
(Bridge Deck Construction)

Section Five: Bridge Deck Construction

This Section covers bridge deck construction in terms of:

- preparing for the deck pour,
- pouring the deck, and
- other work involved in completing the superstructure.

Before the concrete can be placed for a bridge deck, several preparatory activities must be performed, including:

- profiling the beams or girders,
- constructing falsework and forms,
- setting the reinforcing steel, and
- setting the screed rails and deck-finishing equipment.

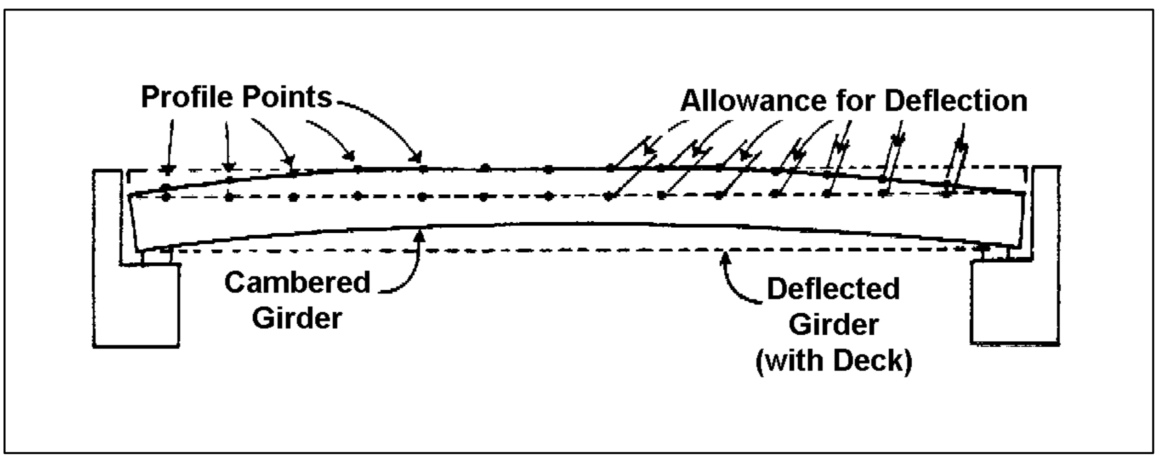
Profiling

The tops of the beams or girders first must be profiled to determine their exact elevations and the amount of build-up needed to form the bottom of the deck. The survey crew determines the elevations at key points along each beam or girder and then uses this data to calculate the build-up at each point. The inspector should:

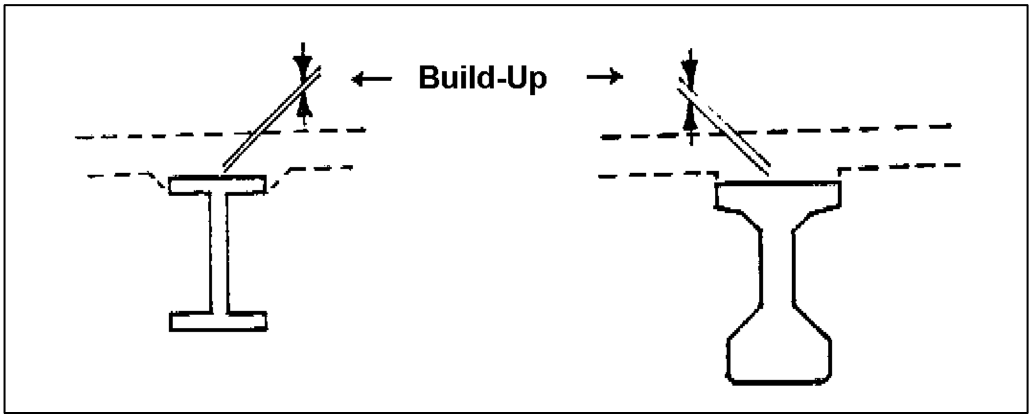
- check the profiling data marked on the beams or girder for general uniformity and any apparent discrepancies;
- see that the contractor uses the profile information to set the deck forms accurately; and
- be aware that survey data is to be submitted to the Bridge Designer.

For erected types of beams or girders such as steel girders and precast concrete I-beams:

- allowance must be made at each profiled point for:
  - ➢ some anticipated settlement of the falsework, and
  - ➢ the prefabricated camber and planned deflection of the beam or girder, as shown below; and

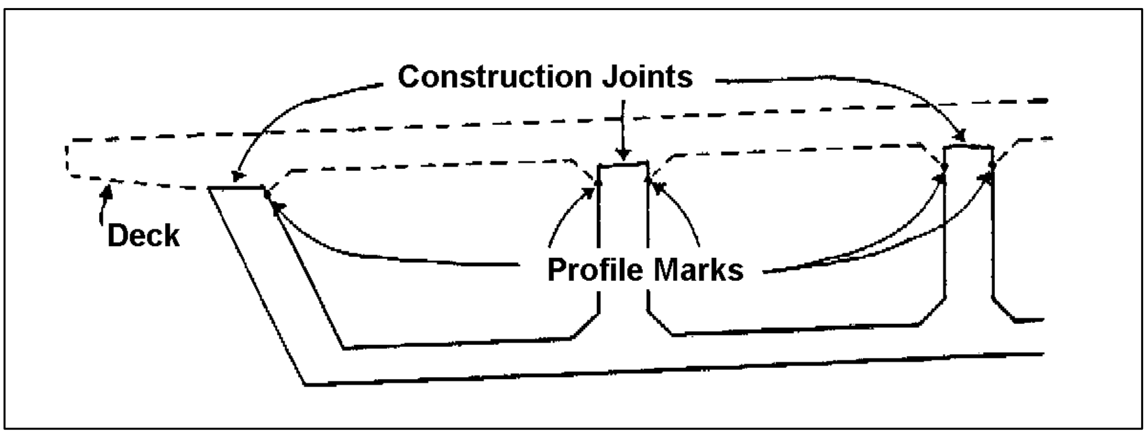


- the "build-up" is marked on the top of the beam or girder as the vertical distance to the bottom of the deck, as shown below (build-up is the elevation between the top of the girder and the top of the deck form).



For cast-in-place concrete box girders:

- little or no allowance is needed for deflection or falsework settlement; and
- a profile line is usually marked along the side of the girder wall as a guide for forming the deck.



Falsework and Forms

As for caps or any other element that requires falsework, see that the falsework for the bridge deck is properly constructed:

- in accordance with the contractor's approved falsework drawings;
- with solid footings or bearings (usually on the beams and girders themselves) without damaging the structure;
- with properly set and adjusted wedges, screws, or jacks to provide uniform bearing at the correct grades; and

- with tell-tales provided to monitor the amount of beam deflection and falsework settlement under the load of the deck.

Check the forms for:
- uniform faces, proper dimensions, mortar-tight joints, and adequate support as for any other cast-in-place structure; and
- correct elevations before the steel is placed.[8]

For box girder decks, remember that the interior falsework and forms must remain permanently in-place. See that:
- any falsework or form supports that bear on the bottom slab are within 10 inches of the girder walls, and
- the box girder cells are cleaned out before the forms are set.

Reinforcement and Expansion Joints

In a typical bridge deck, the key elements of the reinforcing steel include the stirrup extensions from the tops of the beams or girders, two layers of deck steel, and the embedded portions of the steel for such above-deck incidentals as curbs and barrier walls. You should inspect all of this re-steel for the correct quantities, sizes, lengths, shapes, splices, splice staggers, spacing, ties, supports, and clearances as in any other concrete structures.

Expansion joints are often needed for bridge decks – particularly between the ends of the deck and the approach. Although some types of expansion joints are constructed after the deck is poured, you should check the deck details in the plans for any anchor bolts or other parts of the expansion joint that may need to be set in conjunction with the re-steel before the deck is poured.

Setting Screed Rails and Equipment

The equipment used for screeding and finishing the deck must ride on steel rails that are raised above the top surface of the deck.

As the rails are roughed-in, see that:
- they are properly aligned as close as possible to any barrier wall or curb to minimize handwork;
- the saddle supports are:
  - adjustable to different heights,
  - securely set, and
  - spaced at close enough intervals to minimize deflection of the rail; and
- the rails and supports extend far enough beyond the end of the deck to provide all equipment with full access to the deck.

[8] Although it is not specifically required to check elevations before steel placement, it is better to find and correct any forming errors at this point than to wait until after the steel is in place.

After the rails are roughed-in, the deck-finishing equipment must be placed on the rails so that the rails can be set. See that the survey crew and contractor set the grades accurately and uniformly by:

- moving the equipment into position at each saddle support;
- determining the initial, roughed-in elevation of the rail at each support while the equipment is in postion;
- raising or lowering the support to the required elevation; and
- repeating the process throughout the entire length of the deck.

After the rails are set to grade, you must thoroughly check the clearances of the screed equipment:

- at various locations:
  - screed equipment is set at correct skew;
  - across the deck to ensure the proper camber of the equipment to produce the necessary deck cross slope, and
  - along the full length of the deck to ensure uniformity of the rails;
- by measuring at each location from the bottom of the screed to:
  - the bottom forms for the deck thickness,
  - the top of the reinforcing steel for the proper clearances, and
  - the top of any bulkheads;
- by seeing that all clearances are within ± ¼-inch of those specified in the plans; and
- by watching for any deflection of the rails as the equipment moves over them.

Pouring the Deck

A typical deck pour involves five basic types of operations:

1. placing and consolidating the concrete;
2. screeding the mix to produce a uniform surface;
3. mechanically finishing the deck surface, including such activities as straightedging, floating, and texturing;
4. hand-finishing in areas that are not accessible to the mechanical screed and finishing equipment; and
5. curing the deck.

Concrete Placement

The placement and consolidation of the concrete for a deck must generally meet the same requirements as for any cast-in-place structure. As for any other large pour:

- check the plans for any specified pour sequence;
- see that the contractor follows the pour sequence; and
- see that the contractor provides adequate resources to complete the pour within time scheduled for it including:
  - a steady supply of mix,
  - sufficient labor to work the concrete, and
  - standby equipment – particularly for vibrators and any concrete pumps; and
- when a hand vibrator is used, ensure that the contractor follows good vibration methods.

Specifically for bridge decks, you should also:

- see that the mix is placed and consolidated across the full width of the deck in front of the screed;
- make certain that any vibrators attached to the screeding equipment:
  - do not touch the reinforcing steel, and
  - stop whenever the screed stops; and
- monitor the tell-tales for the amount of any deflection and settlement as the concrete is placed.

Screeding

The primary purposes of the screeding equipment are to strike-off the excess concrete and produce a smooth, uniform deck surface. Monitor screeding operations closely to see that:

- the auger uniformly distributes the mix ahead of the screed,
- a slight roll of excess concrete is maintained in front of the screed – but not so much as to force the screed to ride up and over the excess,
- the auger and screed assembly makes as many passes across the deck as needed to produce a uniform surface (without any ridges, streaks or other irregularities behind the screed)[9], and
- if the screed produces a rocky or honey-combed surface, back up the screed and refinish the deck surface.

[9] The screeding operations should also help seal the surface by working the larger aggregates down while bringing up finer paste to the top. If the steel tines in the texturing operation tend to pull aggregates up, the screed is probably not making enough passes.

Finishing

In addition to the screeding equipment, the contractor must provide additional work bridges[10] for such operations as:

- floating (if required),
- tine-texturing (if required), and
- application of curing compound.

Separate float finishing is not always required because the roller type of screed used in most deck screeding performs a similar type of smoothing function – when properly set and operated. However, the contract plans or special provisions may sometimes specify float finishing. In such situations the floating should be done and inspected in much the same manner as for concrete pavement.

You also must check the uniformity of the deck surface with a 10-foot straightedge as for concrete pavement. For a bridge deck see that the surface is within:

- ⅛-inch per 10-feet, if the deck is designed as a final riding surface; or
- ¼-inch per 10-feet, if it is to be covered by a special riding surface or waterproofing membrane.

Whenever the deck will serve as a final traffic-riding surface, tine-texturing is also required. The tine-texture must meet the same types of requirements as for concrete pavement, including:

- independent, self-propelled equipment used only for the texturing operation;
- the proper timing of the texturing to avoid grooves that close behind the tines or tearing the surface;
- the same dimensions and spacing of the grooves.

Handwork

Some hand finishing is needed in areas that cannot be reached by the mechanical screeding equipment. Sidewalks and the areas around the barrier wall and curb steel are common examples. In such areas see that:

- the concrete is properly consolidated and rough-finished around barrier wall and curb re-steel to produce a good construction joint; and
- any sidewalks are uniformly floated and broom-finished as for other sidewalks.

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[10] The *Standard Specifications* call for "a minimum of two transverse work bridges" for these operations. In actual practice, many contractors will try to get by with one. In such cases, the Engineer should determine whether or not the single work bridge can adequately perform these finishing and curing operations.

If the rails for the screeding and finishing equipment are positioned within the width of the deck, you also must see that the handwork includes:

- removing the rails and saddle supports behind the last work bridge;
- filling any voids that result from removing the saddle supports; and
- consolidating, hand floating, and hand texturing the area so that it meets the same requirements as the rest of the deck.

Curing

If the deck is designed as a final riding surface (which most are), both curing compound and water curing are required. See that the curing compound is applied:

- immediately after surface-finishing work is completed, and
- uniformly at a rate of at least 1 gallon per 100 square feet.

For the water curing you should see that:

- the application of the water curing is started:
    - after the concrete has sufficiently set so that the application of the curing medium will not damage the surface, <u>but</u>
    - within 4 hours after completion of the deck-finishing operations;
- if burlap or another type of curing medium is used (and it usually is), it is kept continuously wet for the full curing period of at least seven days; and
- if no curing medium is used, the surface is:
    - kept moist with an atomized fog mist until the concrete is set, and
    - then continuously sprinkled with water for the full curing period; and
- on hot days the surface may need to be misted until the wet curing medium is applied.

If the deck is to be covered with a special riding surface or waterproofing, <u>only</u> the water curing method is used, because the curing compound would hinder the bond with the surfacing or waterproofing.

Completing the Superstructure

After the deck is constructed, the superstructure must be completed by such activities as:

- removing falsework and forms,
- constructing above-deck incidentals,
- constructing the approach slabs, and
- painting (when required).

Falsework and Forms Removal

As for any other cast-in-place part of a bridge, the falsework and forms can only be removed with the Engineer's approval. More specifically for post-tensioned, box girder bridges, the deck falsework for:

- the cantilevered sides of the deck must remain in-place for at least seven days, <u>but</u> be removed before post-tensioning; and
- the bottom of the box girders (the soffit fill) may be removed only after post-tensioning and grouting are completed.

For other types of bridges, the deck falsework must remain in place for at least:

- 10 days and until at least 70 percent of the specified 28-day strength is achieved, or
- 5 days, if the <u>full</u> 28-day strength requirement is met.

Otherwise, the forms for the bridge deck must remain in place for at least seven days, except with the Engineer's approval of a written request for earlier removal.

Above-Deck Incidental

The approach slab at each end of the bridge also must be constructed. The key points to watch for in approach slabs are:

- that all backfill is properly placed and well compacted behind the abutments;
- that expansion joints are constructed in accordance with the plans, including:
  - the correct size and positions of dowels, and
  - the proper angle iron or other joint materials;
- placement of the reinforcing steel; and
- that the surface may be hand-screeded, but the same basic surface finishing requirements apply as for the bridge deck, including the:
  - straightedging tolerances, and
  - tine-texturing requirements.

Painting

Painting is primarily required for steel girders and other metal surfaces. However, the plans or special provisions also may specify painting for concrete surfaces.

When painting is required, see that:

- the surface is cleaned free of dirt, grease, rust scale, curing compound, loose paint, or other foreign material;
- the weather limitations for paint are met, including a dry surface and an air temperature of at least 40° F, a surface temperature 5° above the dewpoint, a humidity less than 80% or as otherwise specified;
- the contractor shall protect traffic, pedestrians, and other surroundings from paint spills or overspray;
- field painting is carried out as specified, usually including (for steel surfaces):
  - spot-painting damaged areas of the prime coat with additional primer paint,
  - a full initial field coat of paint approximately tinted to contrast with the prime coat, and
  - a final finish coat as specified; and
- paint sample is tested, and approved prior to application.

Section Five Quiz

1. In checking the screed clearances prior to a deck pour, which of the following deviations from the plan dimensions should **not** be permitted? (Circle one or more)
   a. a deck thickness ¼-inch thicker than planned
   b. a deck thickness ½-inch thinner than planed
   c. a re-steel clearance ⅛-inch less than planned
   d. a re-steel clearance ⅜-inch more than planned

2. After concrete placement has begun in a bridge deck, which of the following screed equipment adjustments should **not** be permitted? (Circle one or more)
   a. raising saddle supports
   b. lowering the legs of the screed bridge
   c. changing the crown of the screed bridge
   d. none of the above – they are all permissible

3. During the screeding operations in a deck pour, you should see that the screed ... (Circle one or more)
   a. makes only one pass over each part of the deck.
   b. makes at least three passes over each part of the deck.
   c. makes as many passes as necessary to produce a smooth uniform surface.
   d. maintains a small roll of excess mix in front of the screed.
   e. maintains a large roll of excess mix in front of the screed.

4. Which of the following finishing activities is usually required for a deck that will be covered later with a special riding surface? (Circle one or more)
   a. float finishing
   b. checking the surface with a straightedge
   c. tine-texturing
   d. none of the above

5. When tested with a 10-foot straightedge, a bridge deck that is designed as a final traffic-riding surface must be within ... (Circle one)
   a. ½-inch per 10 feet.
   b. ¼-inch per 10 feet.
   c. ⅛-inch per 10 feet.
   d. the tolerances specified in the plans.

6. Which of the following concrete curing methods is required for a bridge deck that will serve as a final traffic-riding surface? (Circle one or more)
    a. airing compound applied immediately after finishing operations are completed
    b. curing compound applied within four hours after finishing operations are completed
    c. water curing starting immediately after finishing operations are completed
    d. water curing starting within four hours after finishing operations are completed

7. Which of the following summarized sequences best reflects the required procedure for removing the falsework and forms for a post-tensioned box girder bridge? (Circle one)
    a. (1) 7 days, (2) post-tension, (3) side forms, (4) soffit fill
    b. (1) side forms, (2) soffit fill, (3) 7 days, (4) post-tension
    c. (1) post-tension, (2) side forms, (3) 7 days, (4) soffit fill
    d. (1) 7 days, (2) side forms, (3) post-tension, (4) soffit fill

8. Which of the following types of above-deck incidentals cannot be poured until after the soffit fill (for cast-in-place box girders) or deck falsework (for other types of beams and girders) is released? (Circle one or more)
    a. curbs along the outer edges
    b. median curbs
    c. barrier walls
    d. sidewalks
    e. sign supports

Section Five Quiz Answers

1. b. a deck thickness of ½-inch thinner than planned
   d. a re-steel clearance ⅜-inch more than planned

2. a. raising saddle supports
   b. lowering the legs of the screed bridge
   c. changing the crown of the screed bridge

3. c makes as many passes as necessary to produce a smooth uniform surface.
   d. maintain a small roll of excess mix in front of the screed.

4. b. checking the surface with a straightedge

5. c. ⅛-inch per 10 feet.

6. a. curing compound applied immediately after finishing operations are completed
   d. water curing starring within four hours after finishing operations are completed

7. d. (1) 7 days, (2) side forms, (3) post-tension, (4) soffit fill

8. c. barrier walls

Section Six: Documentation

This section summarizes the documentation involved in inspecting major structures in terms of:

- measurements as the basis for payment,
- key information and events to be documented, and
- the records and reports used.

Measurements for Payments

The basis of payment for major structures can vary from one bridge to the next. The Special Provisions usually specify the pay items involved, but generally a major structure is paid for on a lump-sum basis, or a combination of the two following categories.

Lump-Sum Payments

Bridges are commonly bid, contracted, and paid for on a lump-sum basis for the entire structure –including all the materials, parts, and operations involved. However, even when lump-sum payment is used, you must still document the quantities of materials used and the operations performed for a detailed record of the structure as constructed.

Line-Item Payments

When line items (or a combination of lump sum and line items) are used, the Special Provisions identifies the specific items, but typical line items might include:

- **structural excavation** – measured in cubic yards calculated from the pay limits specified in the plans and the cross section of the undisturbed ground;
- **piling** – including:
  - furnishing piles – measured in linear feet in accordance with the planned lengths,
  - driving piles – measured in linear feet (meters) from tip to cut-off of in-place piles, and
  - splicing piles – measured per splice for any splices required for a pile length longer than specified in the plans (no payment for splices within the planned pile length);
- **drilled shaft foundations** – measured in linear feet from the completed bottom of the shaft to the planned top elevation unless otherwise specified in the Special Provisions;
- **reinforcing steel** – measured either:
  - as a lump sum for all reinforcement specified in the structure, or
  - in pounds of reinforcement used, determined by measuring the lengths of each bar size and converting the lengths to pounds;

- **concrete** – measured in cubic yards of concrete placed, based on the calculated volume of the structure and including all forms, falsework, joint materials, consolidation, finishing, and curing operations and materials;
- **structural backfill** – measured in cubic yards calculated from the pay limits specified in the plans;
- **structural steel** – measured either:
  - as a lump sum for the entire structure, or
  - in pounds, using AASHTO conversion factors to determine the net weight;
- **precast concrete** member – measured by the precast unit, including all concrete, reinforcement, curing materials and other materials involved; and
- **post-tensioning** for cast-in-place concrete – measured as a lump sum for the structure, including all duct work, anchor plates, prestressing cables, grout, and other materials required to complete the post-tensioning.

Key Information and Events

Because bridges can be relatively large and complex, there are many types of key information and events that must be documented throughout bridge construction – from the initial staking through completing the superstructure.

Alignment and Grade Controls

The detailed information for a bridge's alignment and grade controls is documented in the survey crew's records. At times you may need to refer to these detailed survey records, but your primary responsibility in the documentation of alignment and grade controls is to record such key surveying events as:

- initial layout staking, cross sectioning before structural excavation, checking the elevations of footings or other foundations, setting grades for beam or girders, and
- adjusting screed rails for deck construction.

Structural Excavation

Relative to structural excavation, you should document such key information as:

- any unusual soil, rock, or water conditions encountered;
- any existing utilities or other subsurface structures not shown in the plans;
- any bracing or side slopes used or needed for safety; and
- any special bedding, foundation material or water control measures used by the contractor to achieve an adequately firm and uniform foundation.

Pilings

When pilings are used as part of the bridge's foundation, you must document:

- the types, dimensions and quantities of the pilings, including:
  - the date delivered,
  - heat numbers and certification, and
  - the pile lengths;
- the pile-driving equipment being used, including the:
  - drop, single-action or double-action type,
  - make and model,
  - manufacturer's energy rating,
  - weight of the hammer, and
  - fall distance of the hammer or stroke;
- the number of blows used on each pile to penetrate:
  - the first 10 feet, and
  - each 1-foot interval thereafter;
- the final bearing value for each pile;
- the location, length, and source of material for any pile splice; and
- the pile number, length, and any subsequent use of all pile cut-offs.

Drilled Shaft Foundations

For drilled shaft foundations, complete the Drilled Shaft Inspection Report (see the *Construction Manual*, Chapter VI) which includes:

- the diameter of each drilled shaft;
- the amount of concrete placed in each shaft and the calculated yield;
- any problems such as caving-in or water seepage encountered during drilling – and the approved method used by the contractor to overcome such problems;
- the depth of each completed shaft; and
- the methods and equipment used in placing concrete (such as the number and lengths of tremies, and depth of consolidation, etc.).

Reinforcing Steel

As you inspect the placement of reinforcing steel**,** you should:

- document the sampling and certification information for all reinforcing steel;
- verify the actual quantities and lengths of each bar size and shape placed in the structure in relation to the specified plan quantities; and
- document any discrepancies in spacings, ties, supports, or tolerances – and the corrective actions taken by the contractor.

Falsework and Forms

The key documents involved in the construction of the falsework and forms for bridge construction are the contractor's approved falsework and forms drawing. Your primary concern is to see that the actual falsework and forms are constructed in accordance with these drawings – and the contract plans.

You should also document:

- any discrepancies or deficiencies in the construction of falsework and forms visited by the contractor's engineer;
- any special forming materials or techniques that are used but not detailed in the contractor's drawings;
- soil types encountered; and
- any discrepancies or deficiencies in the construction of falsework and forms and the contractor's corrective actions.

Concrete Operations

For most concrete elements in a bridge – including footings, columns, walls, caps, and cast-in-place girders – the documentation needs for the concrete placement are generally the same as for other concrete structures, including:

- the air temperature and weather conditions during the pour;
- the types and quantities of equipment used (including standby equipment);
- collecting and checking the delivery ticket for each load of concrete with particular attention to:
  - the class and design strength of the mix, and
  - the batch time for the load;
- sampling and testing information, including the:
  - mix temperature,
  - slump,
  - air content, and
  - numbers and strengths of specimens prepared;
- the specific reasons for rejection of any rejected load;
- the times for each station within the pour at which:
  - concrete is placed and consolidated,
  - surface finishing starts and ends,
  - curing compound is applied, and
  - placement is suspended and later resumed due to lack of mix or equipment breakdowns;
- information on the forms and falsework during the pour, including:
  - any displacement of the forms and the contractors corrective action, and
  - the amount of any falsework settlement as indicated by the tell-tales; and

- any unacceptable practices in placing, consolidating, finishing, and curing the concrete – and the contractor's corrective actions.

Specifically for bridge decks, you should also document:
- the locations and results from straightedge checks,
- the locations and results from checking the dimensions of tine-texturing, and
- the station-by-station times for application of the water cure as well as the curing compound.

After the concrete pour is completed, you should document:

- the dates and times at which:
  - any falsework is released,
  - the forms are removed,
  - Class I and II finishing work is undertaken, and
  - curing compound is applied to formed surfaces;
- the general condition of the formed surfaces after forms removal, with particular attention to such deficiencies as honeycombing, rock pockets, exposed steel, or other surface irregularities;
- the strength results from compressive-strength cylinder breaks as they are received from the lab; and
- key information on any structural backfill, including:
  - the dates backfilled, and
  - results from density tests.

Structural Steel

For steel girders and other structural steel, the primary documentation needs are:

- the heat numbers and Certificates of Analysis for the steel;
- any defects found in the prefabricated steel members prior to erection;
- the dates and sequence of erecting and securing the steel members; and
- record blot torque readings.

Precast Concrete

Similarly, for concrete I-beam or other precast concrete items, you should document:

- confirmation of the ADOT stamp and Certificate of Compliance for each precast item;
- any defects found the precast item; and
- the dates and times of such activities as:
  - erecting the precast beams,
  - pouring the intermediate diaphragms, and
  - pouring the pier and abutment diaphragms.

Post-Tensioning Operations

When post-tensioning is required for cast-in-place structures, you should document such key information and events as:

- any problems encountered in constructing the duct work in relation to the re-steel;
- checking the duct work for interior clearance and pressure after the girders are constructed, with particular attention to the location and corrective measures for any obstruction or leakage;
- the sampling and testing of the prestressing cables;
- the installation of the cables;
- those events which must be completed before tensioning can begin, including:
  - the 7-day curing,
  - achieving the required strength for jacking,
  - removing the side forms, and
  - checking the calibration of load-monitoring equipment;
- the tensioning operations, including:
  - the tensioning sequence, and
  - the loads and elongation of each cable group; and
- the pressure grouting operations, including:
  - the efflux time from the flow-cone test,
  - any leaks or problems encountered in maintaining adequate pressure and the corrective actions taken, and
  - the removal of the valves after grouting is completed.

Completing the Superstructure

As the superstructure is completed, you should document such key events as:

- the removal of the deck falsework and forms;
- the forming, pouring, finishing and curing of above-deck incidentals; and
- any painting operations.

Records and Reports

Most of the documentation needs for major structures are recorded in the same basic records and reports used for other concrete structures. However, piles require special detailed records that are separate from the documentation for other bridge construction records.

Basic Documents

The basic records and reports used to document the majority of the operations in bridge construction are the:

- Daily Diary – as for all inspection work;
- Computations Record Field Books – which is often referred to as the "Pour Record" in concrete construction work;
- materials delivery, sampling and testing documents, including:
  - Certificates of Compliance and Analysis,
  - green tags or other evidence of pre-testing,
  - delivery tickets and suppliers invoices,
  - sample tabulation cards, and
  - Cylinder Reports for test results; and
- Structure Reports and Diagrams.

Piling Records

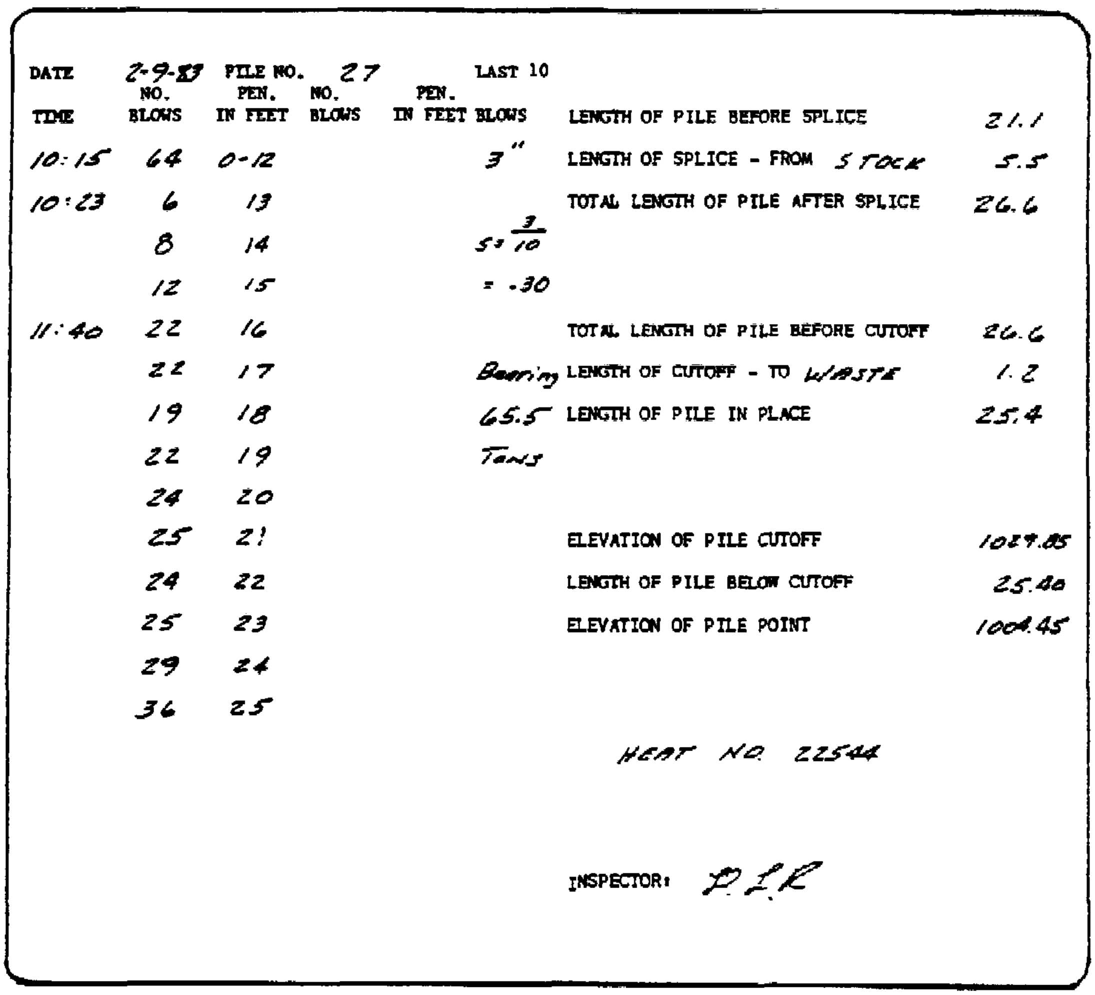
The key elements in the detailed documentation of pile-driving operations are the Pile Record Book and the Pile Record Summary.

The Pile Record Book is a separate book used exclusively for the field notes and computations for pile-driving operations. It includes:

- an index;
- a summary diagram of the locations, pile numbers, types and planned (estimated) lengths;
- a summary of the hammer data, including the:
  - type,
  - make and model,

- ➢ hammer weight.
- ➢ hammer fall distance or stroke, and
- ➢ appropriate bearing-value formula;

- a Pile Record Sheet for each pile (as shown on page 78), including the:
  - ➢ date and pile number,
  - ➢ penetration record,
  - ➢ final bearing value,
  - ➢ lengths of the initial pile, any spliced portions, the cut-off, and total-in-place,
  - ➢ piles heat number, and
  - ➢ inspector's signature or initials; and
- a summarized inventory of all pile cut-offs which accounts for all cut-off lengths as:
  - ➢ "in yard" (or "on hand"),
  - ➢ "contractor use," or
  - ➢ "waste".



DATE 2-9-83 PILE NO. 27 LAST 10

TIME	NO. BLOWS	PEN. IN FEET	NO. BLOWS	PEN. IN FEET	BLOWS
10:15	64	0-12			3"
10:23	6	13			
	8	14			S = 3/10
	12	15			= .30
11:40	22	16			
	22	17			Bearing
	19	18			65.5
	22	19			Tons
	24	20			
	25	21			
	24	22			
	25	23			
	29	24			
	36	25			

LENGTH OF PILE BEFORE SPLICE 21.1
LENGTH OF SPLICE - FROM STOCK 5.5
TOTAL LENGTH OF PILE AFTER SPLICE 26.6

TOTAL LENGTH OF PILE BEFORE CUTOFF 26.6
LENGTH OF CUTOFF - TO WASTE 1.2
LENGTH OF PILE IN PLACE 25.4

ELEVATION OF PILE CUTOFF 1029.85
LENGTH OF PILE BELOW CUTOFF 25.40
ELEVATION OF PILE POINT 1004.45

HEAT NO. 22544

INSPECTOR: D.L.R

Pile Record Sheet

As shown in the example on page 80, the Pile Record Summary accounts for the quantities of pilings, including:

- the lengths of the initial pile and any spliced portions,
- the cut-offs and resulting in-place lengths,
- the eventual disposition of the cut-offs (including the pile number to which it was spliced, if re-used), and
- any splices that qualify for additional payment.

SHEET 1 OF 1

ARIZONA DEPARTMENT OF TRANSPORTATION

PILE RECORD SUMMARY

Project No. I 10-5(16) Structure Mule Creek Bridge

PILE NO.	LENGTH OF EACH PIECE 1st	2nd	3rd	4th	TOTAL L. FT.	CUT OFF	PILING IN PLACE	RE-USED L. FT.	PILE NO.	LEFT ON HAND	CONTR. USE	SPLICES EACH	REMARKS
1	30				30.0	1.7	28.3	--		1.7	--	--	
2	30	6			36.0	3.0	33.0	3.0	9	--	--	1	
3	16	16			32.0	2.4	29.6	--		1.0	1.4	--	
4	16	16			32.0	1.3	30.7	--		1.3	--	1	
5	34				34.0	2.0	32.0	--		1.5	0.5	--	
6	34				34.0	6.0	28.0	6.0	2	--	--	--	
7	34				34.0	3.5	30.5	--		3.5	--	--	
8	30	4	4		38.0	1.6	36.4	--		1.6	--	2	
9	30	3			33.0	--	33.0	--		--	--	1	
10	30	4			34.0	4.5	29.5	4.0	18	--	0.5	--	
11	30	4			34.0	2.0	32.0	--		--	2.0	1	
12	40	10			50.0	3.0	47.0	--		3.0	--	1	
13	45				45.0	0.7	44.3	--		0.7	--	--	
14	45				45.0	1.2	43.8	--		1.2	--	--	
15	18	18	18		54.0	8.0	46.0	8.0	19	--	--	1	
16	46				46.0	0.7	45.3	--		0.7	--	--	
17	46				46.0	1.4	44.6	--		1.2	0.2	--	
18	40	4			44.0	0.3	43.7	--		0.3	--	--	
19	40	8			48.0	3.8	44.2	2.0	21	1.7	0.1	--	
20	44				44.0	0.2	43.8	--		0.2	--	--	
21	44	2			46.0	1.1	44.9	--		1.1	--	--	
22	44				44.0	0.3	43.7	--		0.3	--	--	
	766	95	22		883.0	48.7	834.3	23.0		21.0	4.7	8	TOTALS

Pay Quantities

Furnishing & Driving (L) 834 L.Ft. Prepared by: J. R. Gentry Date 3/3/83

Furnished Non F.A. (M) 21 L.Ft. Title Resident Engineer

No. of Splices (M) 8 Each Checked by: Date

FIELD REPORTS SERVICES

10-4701 1/76 (Formerly 10-2336)

Pile Record Summary